Clinical Methods in Ophthalmology

SECOND EDITION

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JAYPEE

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OPHTHALMOLOGY

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Second Edition

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Preface to the Second Edition

At the beginning of their career, the trainee house surgeons and the post-graduate students of ophthalmology get puzzled as to how to start examining the patients systematically, how to use the diagnostic instruments precisely and which investigations are to be ordered for arriving at the diagnosis. There is no such single book that can guide them in this regard. This book is a humble effort to fill up this gap. This book is expected to guide them towards a systematic approach to ophthalmological examination.

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Preface to the First Edition

At the beginning of their career, the trainee house surgeons and the postgraduate students of ophthalmology get puzzled as to how to start examining the patients systematically, how to use the diagnostic instruments precisely and which investigations are to be ordered for arriving at the proper diagnosis in a short period. Morever, the recent fleet of newer instruments leave them perplexed.

The authors who are working as clinical tutors of ophthalmology in different teaching hospitals feel the problem of the new trainees. They believe that there is no such single book that can guide the trainees in this regard at the beginning of their career.

This book has been written to fill up this gap. The book is expected to guide them towards a systematic approach to ophthalmology and help them learn the handling of the basic instruments faster.

This book embodies the compactness of presentation and reflects the way we teach our students.

We sincerely thank our colleagues who helped us in preparing this book. Dr Souvik Banerjee has helped us in preparing some portions of the book. Dr Nilay Majumdar, Shri Tamonash Bhattacharjee and Dr Somenath Ghosh have helped us in preparing the illustrations.

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Chapter 1

History Taking and Vision Recording

HISTORY TAKING

As in other branches of medicine, a good preliminary history is important in ophthalmology too. A good history helps the clinician to decide which part of the eye is to be examined in greater detail. Remember, history taking is not an alternative to clinical examination.

CONCERNS OF THE PATIENT

Majority of the patients come to the ophthalmologist directly. Only a few are referred to by practitioners of other disciplines for expert opinion.

CHIEF COMPLAINTS

1. Disturbance of vision
2. Pain in and around eyes, headache
3. Discharge and watering
4. Redness of the eye
5. Itching and/or difficulty in bright light
6. Disfigurements of the eyes.

Disturbance of Vision

It may be fall of visual acuity for distant or near, poor vision at night or in dim light, loss of part of visual field or appearance of spots or floaters in the field. Double vision may be represented as dizziness as well as dimness by some patients.

Among causes of acute fall of vision, central retinal arterial occlusion needs prompt action. Other causes are central retinal venous occlusion, retinal or vitreous haemorrhage in visual axis, optic neuritis, methyl alcohol poisoning, acute angle closure glaucoma, temporal arteritis, etc. Causes of gradual fall of vision are the refractive error, senile cataract, open angle glaucoma, senile macular degeneration, diabetic maculopathies, etc. Important causes of poor vision at night are vitamin A deficiency in children, retinitis pigmentosa, open angle glaucoma, high myopia and early lental opacity. Secondary vitamin A deficiency in adult from liver diseases and choroidal atrophies and degeneration also can produce night blindness.

Visual field defect if involves the macular vision or of acute onset, are usually complained of but slowly progressive defects of peripheral vision are not generally noted by the patients. Field defects are described by patients in many ways. Patients may report as inability to see an object of interest with an eye. This is usually found in macular lesions. Patient may describe floaters or vitreous haemorrhage as some shoots in front of eye. In the event of peripheral field defect they may complain of stumbling on objects lying on the way or colliding with objects on the side. Defects in central field are commonly found in CSR, macular degeneration, optic neuritis, etc. Peripheral field defects are common in open angle glaucoma, retinitis pigmentosa, etc. Vascular lesions of optic pathway, intracranial tumour, toxic neuropathies—all produce characteristic field defects depending on the site of lesions.

Distorted vision, e.g. a straight line may be seen distorted in part of latters may be seen broken in macular degeneration and choroiditis.

Double vision is almost always due to weakness or paralysis of one or more extraocular muscle, decompensated phoria or poor fusional reserve being other common causes. A rapidly developing proptosis or fracture of the orbit may produce double vision by producing anatomical misalignment of the eyes. In early cataract, patients may complain of polyopia or multiple images in the eye.

Pain and Headache

Pain in and around the eye and headache are very common causes of seeking advice from an

ophthalmologist. To make a proper diagnosis a detailed history is necessary.

Always note the location, quality, severity, aggravating and relieving factors and association, if any.

Common causes of acute severe pain in eye are acute glaucoma, exposure to welding arc, etc. Moderetely severe pain may be due to iritis, corneal erosion or injury, ophthalmic zoster, corneal ulcer, bullous keratopathy, scleritis and episcleritis. Mild pain and foreign body sensation are caused by conjunctivitis, blepharitis, foreign body in the cornea or conjunctiva, dacryoadenitis and orbital cellulitis.

Pain and tenderness on the temple in temporal arteritis, at the inner angle and below the eye in acute dacryocystitis, unilateral headache in migraine are important causes of pain around the eye. Brow pain in a postoperative patient may be caused by endophthalmitis. Pain is aggravated by ocular movement in optic neuritis; near work or reading in refractive error and asthenopia, movement of the lid in corneal injury or foreign body, bullous keratopathy, etc.

Pain and headache may be relieved by sleep in asthenopia, phoria and sometimes in chronic congestive glaucoma. Foreign body sensation of conjunctivitis is relieved temporarily by irrigation of the eye. Vomiting may be induced by migraine, acute angle closure glaucoma. Migraine may be associated with scintillating scotoma also.

Discharge and Watering

The quality and amount of discharge and watering are important for diagnosis. Note association, if any, and also note aggravating factors.

The thick purulent discharges in neonate that exude from the eye on pressure and fill rapidly after cleansing are suggestive of gonococcal ophthalmic neonaturum. Mucopurulent discharges that glue the lids during sleep and associated with foreign body sensation suggest bacterial conjunctivitis. Thin watery discharges in viral conjunctivitis and keratitis, ropy discharges with itching in allergic conjunctivitis and mucoid discharges on pressure over of inner canthus and below in chronic dacryocystitis are characteristic features. Frothy discharges along lid margin are found in meibomitis. Watering may be due to a foreign body in cornea or conjunctiva, concretion of conjunctiva or denuded epithelium of cornea in abrasion or trichiasis. Iritis and acute angle closure are also associated with watering and photophobia. Reflexive watering on exposure to wind or staring may be early sign of dry eye. Ectropion and blockage of nasolacrimal pathway causes overflow of tear fluid.

Redness of the Eye

Ask if there is pain associated with redness. Redness with severe moderate pain is commonly seen in acute angle closure, iritis and iridocyclitis, corneal injury, ulcer or foreign body, scleritis and episcleritis, etc. Redness with mild pain or foreign body, sensation are caused by conjunctivitis, blepharitis, etc. Redness with severe itching and watering is found in acute allergic conjunctivitis. Blood in anterior chamber (hyphaema) if presented early, looks red.

The most important cause of painless red eye is subconjunctival haemorrhage. The colour is bright red. Ask for any history of trauma in or around eye, blood dyscrasia, hypertension, diabetes mellitus, etc. Subconjunctival haemorrhage may be found in infections like whooping cough, measles and also in conjunctivitis.

Itching and/or Photophobia

Itching is predominantly found in allergic conjunctivitis, angular conjunctivitis and blepharitis. Anterior uveitis and cornea affections including keratoconjunctivitis are associated with photophobia. Early lental opacities cause glare and some photophobia. Photophobia may be present during attacks of narrow angle glaucoma.

Disfigurement of the Eyes

The complain may be a spot/growth of swelling which may be on lids, cornea, lens, conjunctiva, sclera. Any white spot may be described as cataract by the patient. Ptosis is usually referred to as small eye. A deviation of eye of long duration may not be complained of at all. Do not ignore what you see but is not complained of.

HISTORY OF PRESENT ILLNESS

Note the followings:

1. *Mode of onset* (a) Acute within hours (b) Rapid within weeks (c) Slow over months.
2. *Duration* Remember a blind or amblyopic eye may be discovered accidentaly.
3. *Association* It may be ocular as well as general. Nasal catarrh and sneezing in hay fever conjunctivitis, whooping cough and hypertension in subconjunctival haemorrhage, diabetes mellitus in glaucoma and cataract are frequent associations.

Past History and Family History

Past history may become important in diagnosis and management. It is not necessarily be confined to eye only. Past history of trauma, surgery, uveitis, use of steroid topically or systemically are also important. At the same time, family history of glaucoma, metabolic disorder, retinitis pigmentosa are also important features.

History of Addiction and Allergy/hypersensitivity to Drugs

Addiction to alcohol, tobacco or intravenous drugs: sensitivity to sulphonamide, acetazolamide, lignocaine or others should be recorded.

Occupational History

It should be noted for any association with the disease as well as for legal matters.

General History

Blood transfusion, diabetes mellitus, hypertension, CVA, renal disease, enlarged prostate, tuberculosis or bronchitis, cardiac problem, bronchial asthma are important in diagnosis and precaution for prescribing drugs which may have an unwanted effect systemically. History of bowel movements, frequency of micturition, sleep etc. should be noted.

Drug History

Long-standing use of drugs, or use of drugs just before onset of an ocular problem should be enquired of. Some drugs can produce ocular pathology or can aggrevate it. A few of them are noted below:

i. Reduced visual acuity or change in visual field may be caused without producing opacity of media:
   Topical Mydriatic, miotic, steroid.
   Systemic Chloroquin, ethambutol, quinine, diiodohydroxyquine, isoniazid, oral contraceptives, vitamin A, digitalis, chlorpropamide, etc.
ii. Raised or altered intraocular pressure:
   Topical Steroid, mydriatic.
   Systemic Tricyclic antidepressant, reserpine, steroid, amphetamine, anticholinergics.
iii. Conjunctival inflammation:
   Systemic Sulphonamide, acetazolamide, proctolol, tetracycline.
iv. Cataract:
   Systemic Steroid (Topical also), nifedipine, chloroquine, quinine.

PLAN OF EXAMINATION

1. Full identification (Name, age, sex, address, guardians/father's name): .....
.....
2. Complaints with duration: .....
.....
3. History of present illness:.....
.....
4. History of past illness:.....
.....
5. History of previous operation:.....
.....
6. Other relevant history:.....
.....

EXAMINATION PROPER

1. General physical examination:
   General health, oral hygiene, bowels, micturition, sleep pattern must be noted.
   Pulse rate, respiration rate, blood pressure, temperature, anaemia, etc. must be examined and noted.
2. Systemic examination of cardiovascular, system, respiratory system and gastrointestinal system must be done.

3. Local examination:
   I. Vision Recording*

	Distant		*Near*	
	Right eye	*Left eye*	*Right eye*	*Left eye*
Without glass				
With glass				
Power of glasses				

   II. Following examinations must be done in both the eyes, separately:
      A. *Eye-balls:* Size, shape, position, direction, movements, cover test, convergence must be recorded.
      B. *Eye-lids:* Position, palpebral aperture, movements, skin margins, cilia, glands, canthi, presence of any swelling/ulcer/patches must be recorded.
      C. *Drainage system:* Puncta, lacrimal sac, lacrimal gland and nasal checkup must be done.
      D. *Conjunctiva:* Lustre, discharge, congestion, nodules, scar, presence of any foreign body in bulbar and palpebral conjunctiva, fornices, plica semilunaris, coruncle must be examined carefully.
      E. *Cornea:* Size, shape, surface, transparency, ulcers, vascularisation, opacity, degeneration, dystrophy, etc. must be looked for.
      F. *Sclera:* Colour, shape, vessels, nodules, ectasia or any other abnormality must be noted.
      G. *Anterior chamber:* Depth, regularity, and contents (hyphaema hypopyon, etc.) must be noted. The angle of the anterior chamber must be examined where indicated.
      H. *Iris:* Colour, pattern, holes, coloboma, vascularisation, nodules, etc. must be noted.
      I. *Pupils:* Relative size, shape, synechiae, reaction to light, (direct and consensual) and reaction to accommodation must be recorded.
      J. *Lens:* Position, transparency, capsule, any other abnormality should be looked for.
      K. *Vitreous:* State, opacities, abnormal contents must be examined.
      L. *Intraocular tension:* It must be recorded digitally and with the help of a tonometer.
      M. Eyes must be examined with the help of a slit lamp.
      N. *Darkroom examination:* It must be examined after full dilatation of the pupils with mydriatics/ cycloplegics:
         a. Preliminary examinaion for fundal glow: Any black opacity against the red fundal glow must be recorded.
         b. Refraction must be done under cycloplegics.
         c. Ophthalmoscopy:
            i. Distant direct with convex lens (+6 DSph) for any opacity.
            ii. Direct ophthalmoscopy to examine media, disc, vessels, arteriovenous crossing changes, periphery and macula.
            iii. Indirect ophthalmoscopy for any additional finding.

VISION RECORDING

Visual function is assessed by measuring a number of variables including visual acuity, glare

testing, contrast sensivity, colour vision, visual fields, etc. There are several methods of measuring each of these components. Specific measurement methods tend to be standardised country by country. However, the objective common to all methods is the goal of determining precise acuities.

Measuring Visual Acuity

Most methods of measuring visual acuity are essentially the same. On a printed or a projected chart, and patient reads a series of letters starting from the top and working their way down. The letters become gradually smaller, with each size corresponding to a visual acuity at a different distance. Although the scale of measurement may differ between "feet and inches" versus the "metric", the most common format for measuring visual acuity is the Snellen's chart—a worldwide standad since 1862. For countries in which distances are measured on a metric scale, normal vision is "6/6", meaning a patient can read at a 6 meter distance exactly what a normal eye should read at 6 meters. On the same chart, however, normal vision is called "20/20" in a country where distances are measured in feet and inches, meaning the patient can read at a 20-foot distance exactly what a normal eye should read at twenty feet. Thus, "6/6" and "20/20" represent the same acuity. Only the unit of measurement differs (Fig. 2.1).

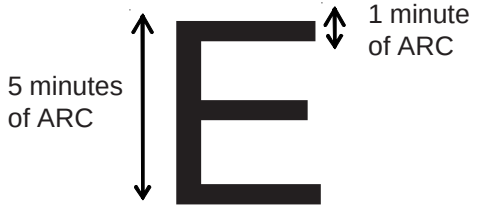


Fig. 1.1: A typical Snellen's letter. The height of the letter is defined by the distance at which it subtends 5 minutes of arc for the limbs subtend 1 minute of arc

Another system for measuring visual acuity is the ETDRS test. "ETDRS" stands for Early Treatment of Diabetic Retinopathy Study. It is a relatively new system for assessing visual acuity that is gaining rapid acceptance world-wide. The ETDRS test assesses visual acuity in a controlled and standardised, high contrast environment. It is similar to the Snellen's chart, in that, characters of decreasing size are presented to the patient for reading. The key differences are that the ETDRS test does not rely on a flat chart or projected image, but an internally illuminated lightbox on which the characters are painted on one translucent surface.

These are two major advantages of this system. Firstly, characters are painted in absolutely black colour. Thus, they are not only darker, but are more uniform and more fade-resistant as compared to those on paper chart. Secondly, internal lighting is variable. By adjusting internal illumination, the examiner can compensate for differing amount of ambient room-light, thereby ensuring that the test is consistent with universal contrast standards.

Contrast Sensitivity

Contrast is the difference in brightness between the light and dark portions of a given object or scene. It is said to be high when the range of difference is large; and low when the range is small. A black object with a white background is a scene with high-contrast but a white object with a white background has low-contrast. As the range of difference in brightness between light and dark portion of an object decreases, the contrast decreases making the features within the scene increasingly difficult to distinguish. The diagnostic specificity of this test is low as it cannot detect specific diseases.

Any given scene will have a measurable range of inherent contrast. This range can be changed in response to the events that are both objective (external factors) and subjective (internal factors, i.e. factors arising from the observer). For example, an outdoor landscape on a sunny day will have high-contrast whereas at night, or through fog or rain, the same scene will have lower-contrast. The same highcontrast landscape may also be perceived as lower-contrast if the

viewer is experiencing glare, has a cataract, is wearing multifocal contact lens, or has a compromised retino-neural system. In these cases, contrast is reduced by subjective or internal events.

Defining contrast sensitivity The degree to which an individual is sensitive to a scene's objective contrast is said to be that person's "contrast sensitivity". As a person's contrast sensitivity decreases, he will have increasing difficulty in perceiving features even within an objectively high-contrast scene. Therefore, it is the result of subjective circumstances that we are pointing when we speak of an individual's contrast sensitivity.

Perception of contrast sensitivity is an essential component of functional vision. The ability to perform normal day-to-day activity can be compromised by poor contrast perception. For this reason, measurement of changes in a person's contrast sensitivity has been increasingly important as a method of assessing any individual's overall functional vision.

Contrast sensitivity testing The term "contrast sensitivity testing" refers to any of the several methods used to quantify a patient's "contrast detection threshold—the point at which the lack of contrast renders an object indistinguishable.

There are several methods for measuring contrast thresholds. Some of these methods, like Regan's charts, present alphabet characters at multiple levels of contrast, etc. are collectively known as "Low-contrast letter identification, tests". However, the principal method for contrast assessment, in use since 1984, is the sine-wave contrast sensitivity test.

Many researchers believe that human visual system is composed of separate neural channels which independently respond to and analyse visual informations based on contrast as well as size and shape. The information for all the channels is combined by the brain to create the images we perceive. Based on this knowledge, researchers developed visual testing procedures which try to measure a person's contrast sensitivity via these separate channels. This may be done by using sine-waves. This is consistent with the goal of creating a sensitive test that assesses the performance of each neural channel individually. As sine-wave contrast sensitivity testing measures the ability to see pure space waves, this is the method found to provide the most sentitive and most specific test of individual's contrast vision channels.

Contrast sensitivity test patterns may be presented on a video monitor, or an illuminated disc in a view box or on a wallchart. The fundamental task is to identify the orientation of slanted bars or to read letters of varying contrast. Sine-waves are waves like space patterns and the graphic representations of them are called "sine-wave gratings". As changes occur to each of the various characteristics of light (brightness, colour, contrast and others), the sine-waves representing these characteristics change accordingly. In this way, each subtle change in light prompts a subtle change in the sine-wave pattern which in turn stimulates a different neural channel.

The ability to distinguish simple visual patterns corresponds to the ability to distinguish more complex visual patterns. Visual response to sine-wave gratings correlates well to contrast sensitivity and permits accurate and predictable functional vision assessment for diverse objects.

Visual information is isolated into its component parts; each of which is transmitted to the brain via its own channel. These channels are depicted as narrow-curves; each one corresponding to a different component of light. In this way, sine-wave contrast sensitivity tests each channel, separately. The brain recombines these channels into a single, composite image-depicted as the wide-curve and known as "contrast sensitivity function". It is the sum of all these signals that creates the final image we see.

This is how sine-wave gratings look when used to test contrast. The changes in the character of light prompt changes in the way the sine-wave is depicted on each grating in a typical sine-wave test, different sized gratings measure contrast sensitivity over a range of patterns whose characteristics correspond to those of everyday objects.

Visiogram: Plotting the results of this testing produces a curve representing contrast sensitivity. This curve is called as "visiogram" or "contrast sensitivity function chart". This is a highly accurate diagnostic and monitoring tool for the ophthalmologist.

Pelli-Robson chart: The Pelli-Robson chart is an 86 x 63 cm chart that is hung 1 m from the patient's eye. The letters are equivalent to 6/270 Snellen's letters. This letter chart, counting 8 rows of six letters, arranged in groups of three letters (within each triplet the letters have the same contrast) which are of constant size but vary in contrast. The contrast decreases from above down (contrast in each successive triplet decreases by a factor of 0.15 log units) ranging from 100 to 0.9 per cent. The subject is asked to read the letters until two or more errors are made in a group of three. Incorrectly identifying the letter 'C' as an 'O' is a common error and can be counted as correct. The contrast threshold is taken as the last group in which at least two out of three letters are correctly identified.

Regan chart: The Regan's low-contrast acuity charts are an example of a low-contrast acuity test. Four charts, one each for high-contrast (96%), intermediate-contrast (25%), low-contrast (11%) and very low-contrast (4%) may be presented to the patient under constant illumination. Typically, the normal eye will lose about four lines of Snellen's acuity from the high-contrast (96%) to the low-contrast (11%) chart and seven lines from the high-contrast (96%) to the very low-contrast (4%) chart. A patient's loss of acuity between the higher- and lower-contrast charts is then compared to the standardised nomogram.

10 per cent (Michelson) contrast Bailey-Lovie chart: Baily and Lovie adopted ten 5:4 aspect ratio letters—DEFHNPRUVZ—which has been shown previously to have relatively equal legibility. The chart has a constant number of letters, namely five, on every line and has a characteristic V shape. The letter size progression is constant on the Baily-Lovie chart and geometric, such that the letters decrease in size by a factor of $10^{\frac{1}{10}}$, which equals 1.2589 and approximates a ratio of 5:4. This progression may also be expressed as 0.1 $\log_{10}$ units, and the charts are frequently referred as "log MAR charts" because of this constant logarithmic size progression. This choice of progression means that a 10-line progression down the chart corresponds to a 10 x reduction. Similarly, a 3-line change corresponds to a 2 x reduction, a 5-line change approximates a 3 x reduction, and a 7-line change corresponds to a 5 x reduction. In order to equalise any contour interaction effect, the spacing between letters on a given line is also constant, being equal to the letter's width. The spacing between two adjacent lines is equal to the height of the letters on the lower line and, therefore, equal to the width of the letters of the upper line (Fig. 1.2).

Fig. 1.2: Bailey-Lovie letter chart

The goals of visual acuity testing is to determine the smallest high-contrast letter size a person can see. But visual acuity testing alone has several limitations owing to the relatively small number of retinal cells excited by this test and the large and non-specific range of channels tested by alphabet letters. On the other hand, the goal of sine-wave contrast sensitivity testing is to measure visual response over a wide range of visual stimuli. Sine-wave testing assesses the health of multiple visual channels, one channel at a time. In this way, the contrast perception of

sine-wave gratings more meaningfully corresponds to our everyday perception.

In addition to sine-wave grating charts, low-contrast letter identification test charts have also been developed to assess contrast. These charts range from having single-sized letter formats (the Pelli-Robson chart) to one or more variable-contrast acuity charts (the Baily-Lovie and Regan charts). Although these tests represent improvements over the traditional Snellen's acuity test charts, they are less sensitive and less specific to contrast loss than are sine-wave gratings.

One method of testing contrast sensivity used since 1984 is the VCTS chart. VCTS stands for Vision Contrast Test System and is sometimes known as the "Ginsburg's chart".

A VCTS chart measures contrast sensitivity using sine-wave gratings of varying sizes and contrast to simultaneously test both visual acuity and contrast sensitivity. For both near and far-vision testing, patients must correctly identify the orientation of the lowest-contrast grating they can see.

The visual acuity is a measure of the resolution limit of the visual system. With the VCTS, acuity corresponds to the highest patch that can be seen on the chart. The bracketed contrast sensitivity values on the graph represent the average values for the last patch a person having the equivalent acuity, could see. VCTS chart consists of 5 rows of 9 circular sine-wave grating patches; spatial frequency remains constant across a row and increases down a column from 1.5 to 18.0 cycles per degree. The contrast increases from right to left. The grating is either vertical or tilted clockwise or counter-clockwise 15 degrees, the last patch in each row is blank. The chart is uniformly illuminated and subject is instructed to indicate the orientation of the grating or to respond blank if it is not visible. Contrast threshold is taken as the contrast prior to the first incorrect or blank response.

A new version of the Vistech chart (Fig. 1.3) incorporates some of the design features suggested by the American Academy of Ophthalmology which was missing in the original. in addition, a spin-off from the Vistech, the CVS-1000 has recently been shown to have superior repeatability to the original Vistech.

There may be difference between the acuity values obtained using the VCTS and those obtained through other means. These differences may occur for two reasons:

1. Different letters have different visibility. A person may have equal ability to identify an "E" in the 20/30 row and an "L" in the 20/20 row. The individual's final score will depend on the following: (a) Luminance of the test conditions, (b) to what extent the patient is pushed to respond, and (c) how well an individual can guess, etc.
2. Acuity has poor sensitivity to visual losses caused by other than spherical refractive error. Losses due to astigmatism, cataracts and other disorders cannot be quantified as accurately with acuity, as they can with contrast sensitivity. Consequently, a patient typically will show larger losses in contrast sensitivity that in acuity if the loss is due to other than spherical refractive error.

It is important to note that, if an individual can read any 20/20 letters, then he must have sensitivity at 18 cycles per degree. However, his threshold at 18 cycles per degree may be above the contrast levels available on the VCTS. The patient may have to skip back to the previous line to be able to see a grating.

The diagnostic specificity of this test is low, as it cannot detect specific disease. Abnormalities have been associated with a variety of diseases including cataract. Patient with cataract have better contrast sensitivity when tested in dimmer light than when tested in brighter light.

Glare Testing

Glare disability means decrease in the patient's ability to perform a visual task such as reading in sunny day light. It is due to the intraocular scattering of light from a bright source by a cataract. Glare related visual dyfunction is increasingly accepted as a good indicator for cataract surgery. However, cataract extraction and IOL implantation may not eliminate glare sensitivity.

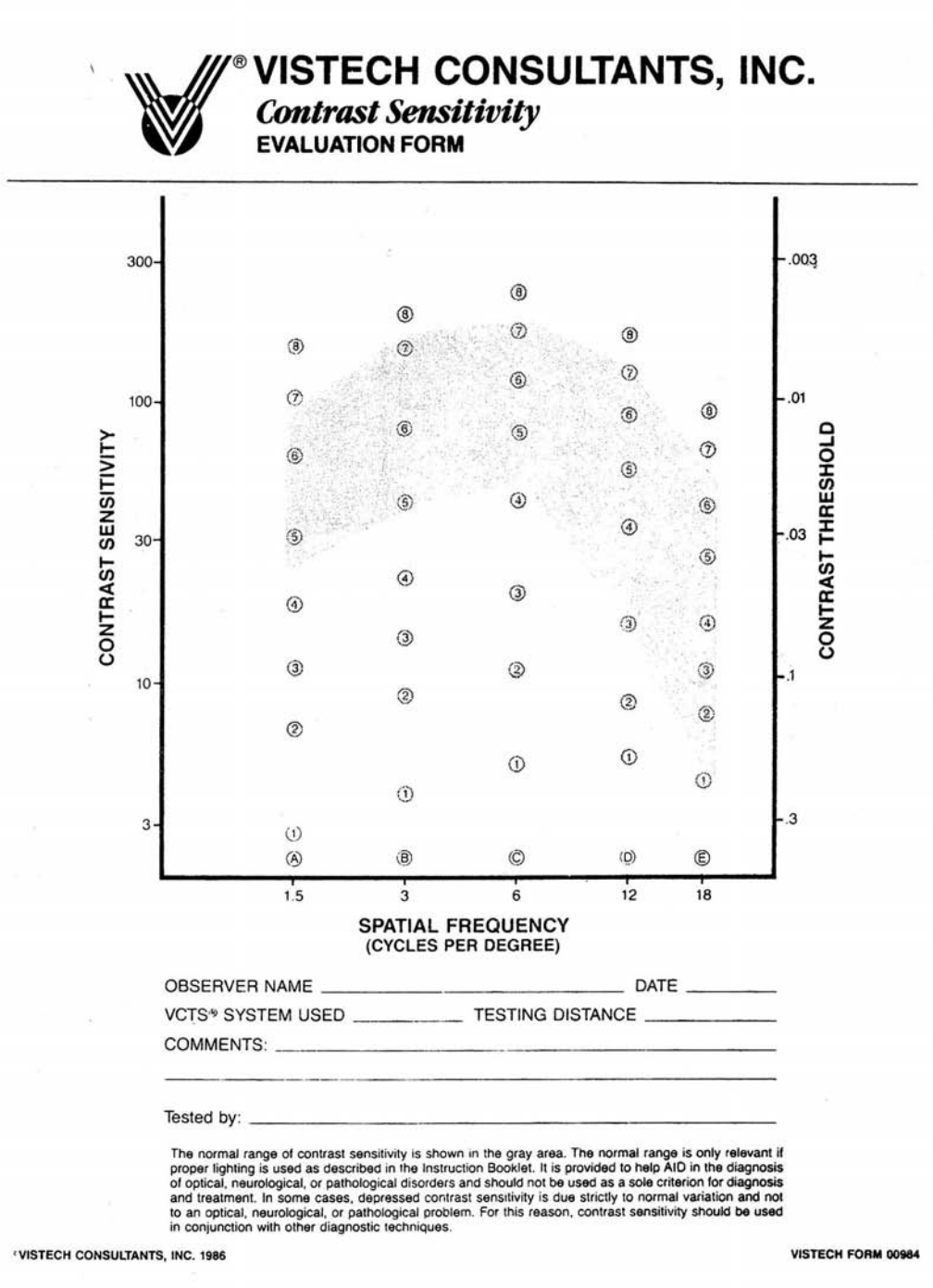


Fig. 1.3: Vistech chart

Postoperative glare sensitivity is due to increased intensity of light entering the eye through clearer media than to light scattering. Target used in glare testing can be grating letter, numbers or Landolt's ring.

The following systems are used to test glare disability.

Brightness acuity tester (BAT) It provides uniform glare source by projecting light onto a white diffusing hemisphere with a viewing part and uses the standard Snellen's chart. The hemisphere is held closely in front of the eye being tested and the patient reads a Snellen's chart through the opening. The light levels on the hemisphere are so set that testing is done at three luminance levels—high, medium, and low. BAT is fast, easy to use and has low false-negative and false-positive results.

Miller-Nadler glare tester It uses Landolt's 'C's on a field surrounded by a uniformly bright light source. The patient views the black C projected on a screen that stays at a constant fairly bright luminance. The C is surrounded by a small circular gray field, the luminance of which changes. The viewer must indicate where the opening of C is. This system has a high-rate of false-positive results and requires more patient education.

VCT 8000 It displays varying contrast sinusoidal gratings in a special viewing system with adjustable illuminance and glare and basically amount to mechanised version of the VCTS-CSF testing charts with the addition of glare testing. The illuminance can be adjusted to bright or low levels, and two glare sources are possible—one that produce bright light surrounding the targets, which is called "day glare" and other that produces a bright light in the centre of the field, which is referred to as "night glare". This also has high-rate of false-negative results.

Chapter 2

Refraction and Contact Lens

REFRACTIVE ERRORS OR AMETROPIA

The eye works like a camera. The cornea and the convex crystalline lens of the eye, work together as a converging lens system, to produce a clear inverted image on the central part of the retina. The pupil acts as the aperture and controls the entry of light according to the illumination of the object of interest.

Accommodation

The diopteric power of the cornea is more or less constant, but the lens changes its power according to the need. To see a distant object, the lens becomes relatively flat and loses some of its diopteric power, to focus a beam of light on the retina. To focus a beam of light from a near object, the lens becomes more convex. The soft lens is held in its capsule, which in turn is suspended by zonules or suspensory ligaments from the ciliary body. When an attempt is made to see the near object, the muscles of ciliary body contract which lessen the pull of the zonules on the lens and its capsule, as a result of which, the lens becomes more convex. This is called `accommodation'. During accommodation, the eyes converge and the pupils constrict. The power to accommodate is greatest in infancy and gradually diminishes with advancing age.

Refractive Error

Ideally, a beam of light coming from infinity should be focussed to a point on the macula. For practical purposes, the distance is considered to be 6 metres. If an eye cannot focus a beam of light from this distance, the eye is considered to have an error of refraction. A refractive error is corrected usually by (i) a lens held so in a spectacle frame, or (ii) contact lens put on the eye, and (iii) occasionally by surgery on cornea—refractive keratoplasty, excimer laser therapy (Photorefractive keratectomy) or by LASIK (Laser assisted *in situ* keratomileusis. An eye without any refractive error is called emmetropic.

Myopia

In this condition, the beam of light from distant object is focussed by the eye in front of the retina. As the eye can focus light from a near object, the patient can see near objects clearly—the condition is also known as near sightedness. It is corrected by appropriate concave lens or minus lens.

In myopia, the eye is usually relatively longer. Such myopia is termed as axial myopia. In old age due to lental sclerosis, the refractive index of lens become greater, as a result, the light is focussed in front of the retina. Such a myopia is called index myopia. In keratoconus, the corneal curvature changes to conical shape, resulting in myopia, which is termed as curvature myopia.

Myopia, if present during childhood, usually increases till adulthood, when the growth of the body as well as the eyes cease, so the myopia also stops progressing. Myopia of more than 8 dioptres may be associated with pathological changes in the retina, called myopic degeneration. These eyes are prone to retinal detachment. A myopic child should wear corrective spectacles, because if the error is uncorrected, he will try to see better by unduly accommodating for distance, which would only reduce the clarity of vision further and result in extraocular muscle imbalance and squint.

Hypermetropia

In this condition, the beam of light from distant object is focussed behind the retina, as the eye

is relatively shorter in respect to the ocular converging lens system. It is corrected by appropriate convex lens or plus lens.

Young people can manage to see objects clearly by accommodating to a greater extent. As the age advances, the power of accommodation decreases and the hypermetropia becomes more symptom producing.

The most common form of high hypermetropia of about 10 dioptres is the absence of crystalline lens, induced by cataract surgery, a condition known as aphakia. In phakic eyes, hypermetropia rarely exceeds 6 dioptres.

As long as accommodation is more active, as in young children, a small degree of hypermetropia causes no symptom, but as the child grows older, the excessive accommodation to maintain clear vision, for both distant and near, induces headache which is relieved by sleep. Moreover, excess accommodation induces an excess amount of convergence which is termed as accommodative convergence. Excessive accommodative convergence may induce squint.

Astigmatism

In this condition, light rays cannot be formed into a sharp image even with the help of any spherical lens. It is usually due to change in shape of cornea. The spherical anterior surface of the cornea in this condition becomes nonspherical. Usually the astigmatism is regular, that is, cornea is relatively flattened in one meridian only. The most common form of regular astigmatism is seen after extraction of lens. Regular astigmatism is corrected by a part of cylinder (plus cylindrical lens) or by a cast of cylinder (minus cylindrical lens), and the orientation of the lens is denoted by degree.

Irregular astigmatism is produced by irregular scarring of cornea. Both the regular and irregular astigmatism can be corrected fully or partly by contact lens.

Astigmatism may be associated with hypermetropia or myopia. Eye strain is the major symptom of astigmatism. As the eye cannot produce a clear image, it tries to accommodate continually to produce a clear image, resulting in eyeache.

Presbyopia

With ageing, the lens material loses its plasticity, and gradually diminishes its power to become more convex while viewing near objects. For emmetropes at about forty, this produces, problems with reading and near work. Presbyopia can be corrected by plus or convex lens. If the distant vision is clear, additional plus lens is put in the lower segment of spectacle glass and is called bifocal.

Anisometropia

Anisometropia means difference in refractive power between the two eyes. Upto 3 dioptres of difference can be corrected by spectacles without causing any discomfort. In anisomet-ropia, the image sizes on the retina become different in the two eyes. Plus lenses produce a bigger image and minus ones, a smaller image. The brain cannot fuse these two different images and the patient experiences diplopia. The problem can be overcome by contact lens.

Severe degrees of anisometropia in young children, if uncorrected, lead to amblyopia. Hypermetropic anisometropia is more apt to produce amblyopia, or lazy eye. In such cases, the eye suppresses the image and virtually becomes non-functioning.

CORRECTION OF REFRACTIVE ERRORS

Steps: Retinoscopy and subjective test.

The aim is to correct the error of refraction when the accommodation of the eye is at rest. In children, the power of accommodation is much greater than in the presbyopic age. For this reason, the accommodation of children is temporarily paralysed by cycloplegics and an objective refraction or retinoscopy is performed. Final glasses are ordered after subjective refraction or if not possible, on the basis of retinoscopy.

Retinoscopy In a darkroom, the patient is seated with the back to the wall. The examiner sits 1 metre in front. A light beam is thrown into the pupil of the right eye, by a plain mirror which reflects the light from a retinoscopic bulb glowing behind the patient, and the part of the retinal

image seen through the pupil is observed through the central hole of the retinoscopic mirror (Fig. 2.1, Plate 1). A self illuminated retinoscope may be used as an alternative. The light is moved by tilting the mirror.

1. In hypermetropia and myopia upto 1 D, the image moves with the light on the pupil while in myopia of more than 1 D, the image moves in the opposite direction of the movement of the light (Figs 2.2A to C).
2. Trial lenses of different power are held in front of the eye and the movement of the image is observed. The power of the trial lens is increased or decreased gradually till there is no movement of the image. The power of the lens is noted.
3. The procedure is repeated in the other eye.

Subjective refraction When the effect of cyclo-plegia is gone, the patient is seated 6 metres from the vision chart. Trial frame is mounted. The left eye is covered. Lens of equivalent power of retinoscopy figure is put on the right eyepiece of the frame. The patient is asked to read from the top of the chart. If he cannot read up to the lower figures, the power is gradually reduced in case of hypermetropia and increased in myopia till he attains the best possible visual acuity.

The procedure is also repeated in the left eye. This is the correct distant vision. In the event of gross anisometropia (over 4 D) patient may experience diplopia and in this event reduce anisometropia by under correction or better try contact lens.

Correction for Presbyopia

The presbyope needs near correction. He is asked to read with each eye, separately the near vision chart, while wearing the distant correction. +1D Sph is added for presbyopes around the age of 40 years and +2.50 D above 55 years. Overcorrection is to be avoided in general except in the following cases:

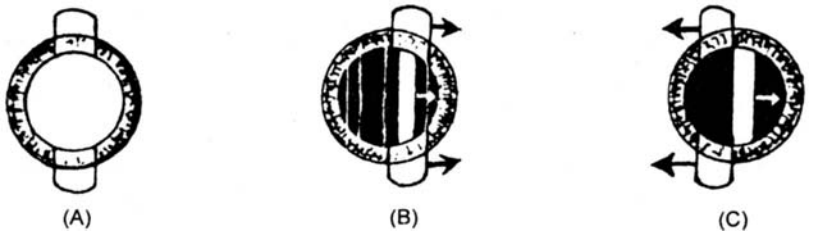
1. If the patients are usually accustomed in seeing near objects (high myopes), keeping close to the eye, a little overcorrection will make them more comfortable.
2. If patient already using overcorrected reading glass and you prescribe correction according to age, the patient may feel inconvenient. Maintain near correction of the old spectacle. Range of comfortable reading should be considered.
3. In macular degeneration, overcorrected 'near glass' helps the patient read more comfortably due to magnification of image.

Problems in Retinoscopy

Full dilated pupil The central corneal curve is steeper than the periphery. Thus the refraction is different in different parts of cornea. Consider only the movement of the central part. A streak retinoscope or undilated pupil gives a better guidance.

Central opacity Corneal or lental, whatever it may be, poses specific problem. Dilate the pupil and do the retinoscopy through the clear area. This will act only as a rough guide. Bank on the subjective refraction.

Irregular astigmatism The movement of the image will be in different directions, not exactly in same or opposite direction of the mirror. Lot of patience will help to overcome the difficulty and



Figs 2.2A to C: *Streak retinoscopy. (A) Point of Neutralisation, (B) 'With movement' in hypermetropia, (C) 'Against movement' in myopia*

assessment of approximate refraction. These patients benefit from hard contact lens.

Keratoconus A swirling image is seen and actual refraction is difficult to estimate. Go for subjective refraction. Contact lens improves vision better than glass.

CONTACT LENS FITTING— A PRELIMINARY IDEA

Contact lens as a means of correcting refractive errors has become popular in the last decades. A great many varieties of contact lenses have come to the market with their own advantages and disadvantages—the age old hard contact lens is being replaced by rigid gas permeable lenses, soft lenses, and now disposable lenses. The hard contact lenses give the sharpest image, and are easy to maintain, but lack in the power to supply oxygen to cornea—hence they cannot be worn for a very long period of time. Rigid gas permeable lenses can supply oxygen to the cornea, but may change shape on hydration or dehydration. Soft contact lenses are more comfortable to the eye but less efficient to correct the refractive error, specially the astigmatic error than the hard lenses and also accumulate deposits on the surface rapidly. Thus maintainace of soft lenses is a bit cumbersome. Recently disposable soft contact lenses have arrived in the market which may be disposed off every month or fortnight when get dirtly. These are a little expensive.

Indications of Contact Lens

1. *Optical*
   a. High and moderate myopia: A larger retinal image give, better acuity of vision.
   b. Anisometropia: Better correction of refractive error and less difference in image size ensures fusion.
   c. Irregular astigmatism: Small corneal opacities produce such irregular astigmatism that cannot be corrected by spectacles. These patients are benefited by contact lens.
   d. Keratoconus: Best corrected by piggy back technique of fitting small hard lens over a large soft lens.
   e. Hypermetropia: They are benefited by better field of vision. In hypermetrope of early presbyopic age the near correction may not be necessary.
2. *Therapeutic*
   Therapeutic soft contact lenses are used in the following:
   a. Bullous Keratopathy
   b. Small corneal perforation
   c. Exposure keratitis.
3. *Low vision aid*
4. *Cosmetic*
   Contact lens of proper tint, colour and painting are used to cover defects of anterior segment like total opaque cornea.

Contraindications of Contact Lens

1. Chronic or recent infection of eye, e.g. chronic dacryocystitis, hordeolum, blepharitis. Contact lens may be used after proper treatment of the infection.
2. Severe dry eye and loss of corneal sensation.
3. Altered anatomic structures, e.g. large filtering bleb, trichiasis, entropion, ectropion, etc.
4. Occupation in dusty smoky climate and when exposed to noxious fumes.
5. In recurrent allergic conjunctivitis, some people may be allergic to contact lens material itself or the soaking solution or preservative.
6. Lack of hygiene.

Basic Instruments Necessary for Contat Lens Fitting

1. Keratometer
2. Slit lamp
3. UV lamp and fluorescein strip
4. Contact lens trial set and cleaning solution
5. A good supply of clean water
6. Topical anaesthetic may be necessary for apprehensive patients
7. A transparent scale
8. A trial set for refraction and overrefraction.

Table 2.1: Vertex distance allowance for lens powers above 5 diopters (calculated for average 12 mm distance) For minus read left-right, for plus read right-left

–	+	–	+	–	+	–	+

Steps of Fitting Common to all Types of Contact Lens

1. Do an accurate refraction.
2. Convert the cylinder of spectacle correction in minus cylinder form.
3. Calculate the power to vertex distance zero as given in the chart (Table 2.1).

Measurement of back vertex distance Put the stenopic slit of trial set exactly in the same slot of the trial frame where the corrective glass was. Ask the patient to close eyes. Pass a Schirmer stip or a fluorescein strip through the slit till it touches the closed lid. Put a mark with the nail of your finger or ink on the paper strip at slit. Measure the length and add 2 mm for lid thickness.

4. Examine the eye with slit lamp to exclude any abnormality or contraindication.
5. Perform keratometry at two meridians.
6. Measure pupil diameter in a darkroom with transparent scale or PD ruler and direct ophthalmoscope set at + 10.
7. Measure the vertical palpebral aperture at the centre. Average is 9 mm.

Fitting of Hard Lens and Rigid Gas Permeable (RGP) Lens

The basic fitting technique of these lenses are the same. A few points should be kept in mind.

Hard lenses These are not permeable to oxygen. So the size of the lens (diameter or ovarall diameter) should be smaller and fitting should never be steep.

RGP lenses It can supply oxygen to cornea. So the overall diameter (OD) may be large. These lenses show a tendency to flatten over use and hydration. Thus a slightly steep fitting is permitted.

Base curve (BC) It is the radius of curvature of the back surface of contact lens in the central optical zone. This curvature is blended peripherally with curvature of higher radius for the purpose of better fitting and comfort. It is directly related to the curvature of anterior surface of cornea. The base curve is selected on the basis of keratometry (Table 2.2).

Overall diameter (OD) It is total diameter of contact lens selected. It is selected smallest in keratoconus. Usually the OD is larger in RGP contact lens. Remember increase the base curve when increasing the OD. Also in aphakia, high myopia loose lid and larger palpebral aperture select a little higher OD.

Optical zone (OZ) It is the central area of the contact lens where the necessary dioptric power remains. It should be 0.5 to 1.0 mm larger than

Table 2.2:							
Diopters	*Radius*	*Diopeters*	*Radius*	*Diopters*	*Radius*	*Diopeters*	*Radius*

the pupillary diameter in dim light. It is described as OZ.

Steps of Fitting of Hard and RGP Lens

1. Based on keratometry at two meridians, select a lens slightly steeper than the flattest meridian in case of low astigmatism and more steep in high astigmatism. Select the trial lens power nearest to calculated contact lens power. Select the overall diameter, depending on refraction, palpebral aperture, type of contact lens (hard or GP) to be prescribed and others.
2. In apprehensive patients, instill topical anaesthetic drop in both eyes. This is necessary in majority of patients for the first trial.
3. Clean the selected trial lens as well as your hands. Dry your hands.
4. Hold the moistened trial lens on the tip of your forefinger or middlefinger of right hand. Ask the patient to look straightforward and a little below. With the fingers of left hand pull the upper eyelid up after turning out the eyelashes. With the fingers of right hand not holding the contact lens, pull down the lower lid. Bring the contact lens steadily over the cornea from the outer side. Leave the contact lens on the cornea just lightly. If decentered, manipulate the lens to occupy position on cornea by manipulating the lids.

   For removal of lens, ask the patient to look straight ahead with lids wide apart. Pull the upper and lower lids further out with index fingers of both hands. Lightly press the lids on the globe and push them firmly behind the contact lens. The lens will pop up.
5. Allow the patient with contact lens in the eye to wait for at least 15 minutes or till the tearing ceases.
6. Assessment of the fit can be made under the following:
   a. *White light:* Ask the patient to move the eye up, down, right and left. During all these movements and extremes of gaze the lens should be within the limbal area.

      Separate the lids and push the lens up by pushing the lower lid and release the lid. The lens should drop down slowly in a vertical path. A steep lens falls slowly and may occupy an upper position whereas a flat lens falls rapidly following a curved path and occupies a lower position.
   b. *Ultraviolet light:* Ask the patient to look down and touch the moistened tip of fluorescein strip to the upper outer bulbar conjunctiva, after retracting the upper

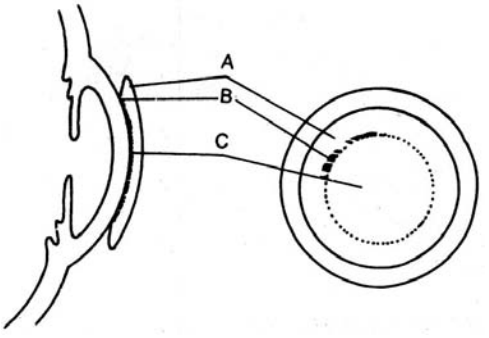


Fig. 2.3: Ideal spherical pattern

A.	Bright green	Thick tear layer	Non lens-cornea touch
B.	Black	No tear layer	Lens-cornea touch
C.	Faint green	Thin tear layer	Minimal lens-cornea touch

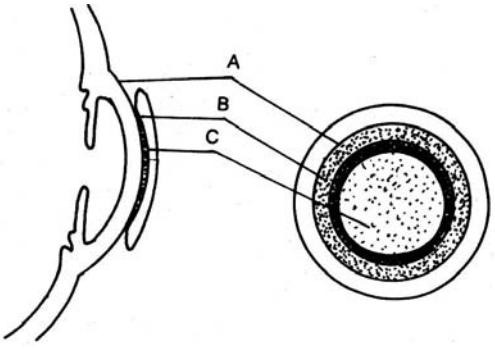


Fig. 2.4: Steep spherical pattern — the dark area represents touch of the contact lens and cornea with absence of fluorescein stained tear

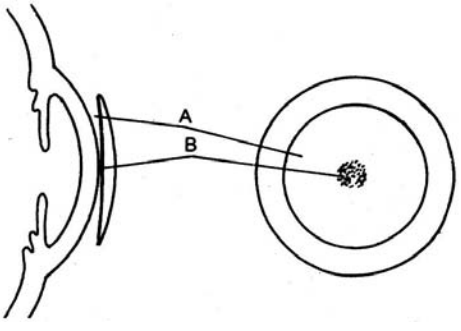


Fig. 2.5: Flat spherical pattern — the central dark area represents touch and absent tear film

eyelid. Ask the patient to blink. Under the following fluorescein patterns may be seen which will indicate change accordingly:

i. Even greenish blue colour with a green band at periphery—ideal fit (Fig. 2.3).
ii. A small central part of the fluorescein, and a thin peripheral band-steep fit (Fig. 2.4). A slight steep fitting may be allowed especially in RGP lenses. An unusually steep lens will show large central pool, may show air bubble in the centre and the dye may take larger time to disappear. A ring of blue line indicates touch.
iii. In case of a flat fit, a large control blue zone of touch will be seen at optic zone with a wide green band at periphery for the excessive edge lift (Fig. 2.5).
iv. Astigmatic cornea may show dumbell or H-shaped touch if the astigmatism is high (Fig. 2.6).

Remember that a very steep lens may not allow fluorescein to enter under it. Also excessive tearing or inadvertent staining of anterior surface of lens give false pattern.

7. Depending on the assessment, change the base curve till you are satisfied with the fit.

When a contact lens of base curve equals to the flattest radius of curvature measured at corneal apex, it is called fitted on K. When the base curve (BC) is steeper than the flatter meridian it is called steeper than K. In the same way a flatter than K is a lens with base curve flatter than the flattest meridian. A lens when fitted steeper or flatter than K, a tear lens is produced which alters the power. A steep lens creates a plus tear lens behind the contact lens and a flat lens creates a minus tear lens behind the lens. Thus if a contact lens of +0.25 D steeper than K is fitted, then –0.25 D must be added to the original power. In flatter than K lens it will be reverse.

8. Perform refraction (overrefraction) with the trial contact lens on. Transform the overrefraction power to the power of back vertex distance zero and add it to the trial contact lens. In case of astigmatism take the spherical equivalent, (or half the astigmatic power). If

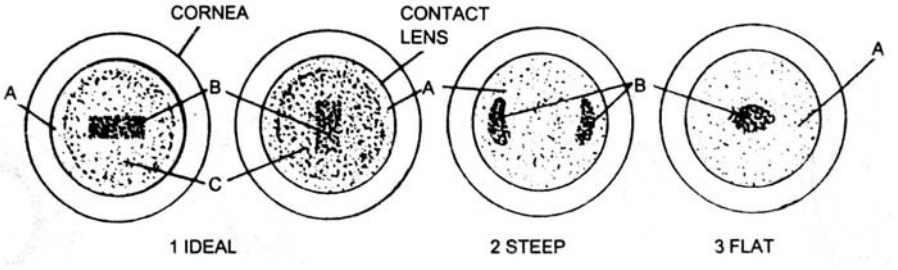


Fig. 2.6: Contact lens

the vision does not improve up to the level as with separate astigmatic correction, go for a toroidal back surface lens or front surface cylinder with truncation or prism ballast.

9. The final order should be as shown below: Eye (right/left)—Basecurve—Power—Optical zone—Overall diameter.
10. For identification, the right lens may be marked R or a dot may be put. Light tint like gray, green, blue, etc. are used for identifying the lens in cleaning solution, water or air.

Fitting of Soft Contact Lenses

In addition to all initial measurement, measure the horizontally visible iris diameter (HVID) with a transparent scale or PD ruler. For all practical purposes it almost equals the corneal diameter. The overall diameter (OD) of a soft lens must be greater than this. The OD should be greater than the vertical palpebral aperture. On average eyes a 13 mm OD is acceptable for initial trial.

The base curve (BC) of soft lens must always be flatter than K. This is for its larger diameter and difference in curvature between cornea and sclera. For the beginner a 0.8 mm addition to the flattest K is ideal for initial trial.

After selection of OD and BC, select a power from trial set. The power should be nearest to calculated contact lens power. Insert the lens as the hard or RGP lens. It may be inserted also as follows:

Ask the patient to look slightly up, separate the lids and put the lens slightly below the centre of cornea and release the lower lid. Ask the patient to blink a few times (Fig. 2.7, Plate 1).

For removal you may use the techniques of hard lens or ask the patient to look down, pull the upper lid up above the upper border of contact lens and slowly push the lens down by the margin of the upper lid, till it is partly displaced on the sclera. Pinch the lens between the index finger and thumb of the other hand.

Before evaluation of fit you will have to wait quite a longer period than the hard lens. If the patient feels irritation a few drops of normal saline or artificial tear may be instilled into the eye with contact lens on.

Evaluation of Fit

The fitting is evaluated in white light only. Care must be given in the following:

a. *Movement* There should be slight movement on looking up, down, right or left. The lens should not expose the cornea during movement, nor it should produce folds on conjunctiva. It should smoothly slide over conjunctiva.
b. *Centering* The lens should centre well. The displacement should not be much.
c. *Edge* The edge of the lens should not compress over the conjunctiva. It should not press over the limbal vessels to produce blanching, or chemosis. The edge should not be rolled by the upper lid.
d. *Refraction* Retinoscopy should be stable with the contact lens on. The blink should not affect the retinoscopy and refraction. When all the criteria are satisfied, do an accurate over-refraction (Fig. 2.8, Plate 1).

Fitting of Disposable Contact Lenses

Different types of disposable soft lenses are available in the market, with different duration of wearing before discarding the lens.

Only a few base curves and overall diameters are selected for trial of these contact lenses. These are easier to fit but are costlier also. At present Ciba, Johnson and Johnson, and Bosch and Lomb are marketting such lenses in India.

AUTOREFRACTOMETER

Autorefractometers indicate highly sophisticated instruments, which allow an observer to determine the degree of ametropia through a small pupil. Here, vergence of emergent rays is primarily determined. The principle is based on the method of indirect ophthalmoscopy wherein a condensing lens in front of the eye brings the emergent rays to focus at a convenient distance.

Patient is placed before the instrument and monocular view is obtained on the CRO screen. The patient is asked to look at an illuminated test-object, which is placed in the principal focus of the objective lens. The rays from this object are collimated by the lens, enter the pupil as a parallel beam, and if the eye is emmetropic, are focussed on the retina. From this image, light emerges from the pupil again as a parallel beam and is focussed by the objective lens at the position of the test-object. It is usually evident for the examiner, seeing at the constantly keeping two dots, focussed at the centre of the pupillary aperture on the screen. In myopic eyes, convergent emergent rays producing image will be formed at a nearer point. In hypermetropic eyes, divergent rays' image will be formed farther away. By moving the joy stick, the two dots can be approximated and degree of ametropia is recorded automatically (Fig. 2.9, Plate 1).

Models of autorefractometer available are Nidek AR-800, AR-2000, Biophysic, Alcon, etc.

Advantages

1. Judgement of ametropia, without mydriasis
2. Accurate results
3. Time saving
4. Correct cylinder adjustments
5. Accurate astigmatic axis
6. Reliability judged automatically
7. Simultaneous keratometry results in some models.

Disadvantages

1. False results in children and high hyperopics
2. Suspicious values in hazy media
3. Difficult to perform in eccentric pupil
4. Fundus assessment cannot be done in single sitting
5. Too much dependence on sophistication obscures the art of retinoscopy.

PIN HOLE, STENOPIC SLIT AND CROSS CYLINDER

Pinhole test It gives the maximum expected visual acuity. When the visual acuity is less due to refractive error, it is improved with pinhole. Spectacle lens may not improve the sight to the same extent because pinhole can also work in cases of irregular astigmatism. The diameter of a pinhole is 1 mm.

Pinhole cannot improve vision in cases with macular function defects (central scotoma), neurological defects and in hazy media due to lental or vitreous opacity (Fig. 2.10, Plate 1).

Stenopic slit It is used in cases of irregular astigmatism where refraction is not possible. It also improves vision in cases with keratoconus. When there is cylindrical error, vision improves, while slit is in the axis (i.e. opposite to the error). The position of the slit in which the best possible vision is obtained, is noted. Then convex or concave lenses are placed in front of the slit; the strongest convex or weakest concave lens which gives the maximum acuity is the measure of refraction in that meridian. The slit is turned through 90^{o} and the same procedure is repeated. In this way, the refractions of the two principal meridians are determined (Fig. 2.10, Plate 1).

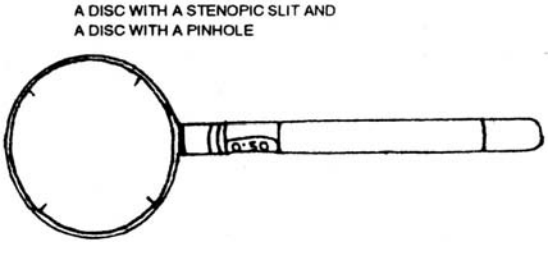


Fig. 2.11: A cross cylinder

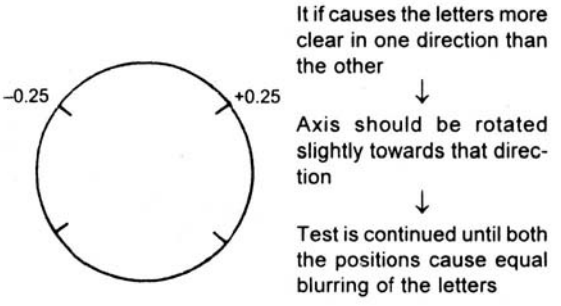


Fig. 2.12A: Axis determination

It is also used for the Fincham's test which helps differentiate the haloes formed by immature cataract and angle closure glaucoma (due to corneal oedema). The halo breaks down in cataract but remains intact in glaucoma.

Cross cylinder This lens is a combination of –0.25 D sph and +0.50 D cyl (Fig. 2.11). This

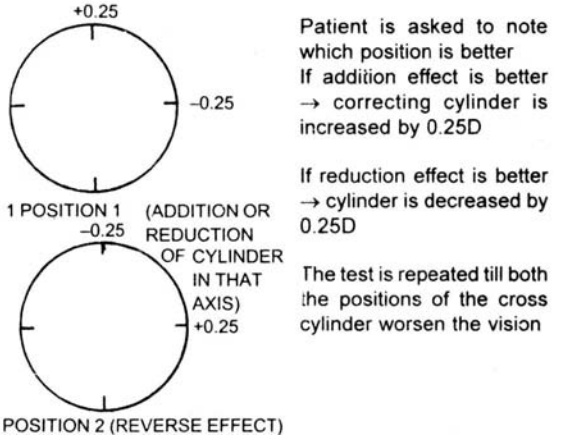


Fig. 2.12 B: Determination of power of the cylinder

makes one axis to be weak concave, the other one weak convex. This is used to determine the axis and also to determine the power of the cylinder (Figs 2.12 A and B).

Chapter 3

Examinations of Lid, Adnexa and Orbit

EXAMINATION OF EYELIDS

Normally, the lids cover part of the globe and impart a protective function. The lids close in apprehension of danger; with each blink the upper lid sweeps over the cornea and spreads tear fluid to keep it clean and the surface wet and smooth. The meibomian secretion imparts stability to the tear film. Proper apposition of the lids to the globe keeps the puncta lacrimalis in contact with the lacrimal lake and thus helps drain the excess of tear fluid. Derangement of any one or more of the above functions, hampers proper functioning of the eye. During examination of lids, the above functions should be kept in mind.

EXAMINATION

a. Look for any asymmetry of the upper lid margin of the two eyes. It should cover only the 12 O'clock position at the limbus while looking straight ahead. Is the upper lid drooping to cover more of the cornea?—suspect ptosis (Fig. 3.1).
b. Is the sclera above visible?—suspect exopthalmos/proptosis (Fig. 3.2).
c. Are the lid margins everted or inverted?—ectropion/entropion (Fig. 3.3, Plate 1).
d. Is there any swelling on the lid on or near margin?—stye or chalazion (Fig. 3.4, Plate 2).
e. Is there any ulcer on the lower lid—suspect basal cell carcinoma.
f. Is there any yellowish patch on the lids—xanthelasma (Fig. 3.5, Plate 2).
g. Are the lashes misdirected?—trichiasis.
h. Are there any lice or nits on the eye lashes? (This examination is greatly helped by magnification—suspect blepharitis).
i. Dry scales or frank ulcers may be present at the lid margins in squamous or ulcerative blepharitis, respectively.

The above initial examination will reveal the most pathology involving lids. Detailed examination and further history taking will help to arrive at a proper diagnosis. Investigations may be needed to establish the cause of disability.

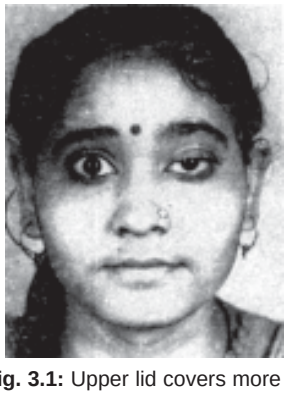


Fig. 3.1: Upper lid covers more of the cornea than normal in ptosis (left eye)

History Taking and Examination of a Ptosis Suspect

As the causes of ptosis are numerous, a detailed history is of much importance. The following points are essential to note:

i. Age and mode of onset

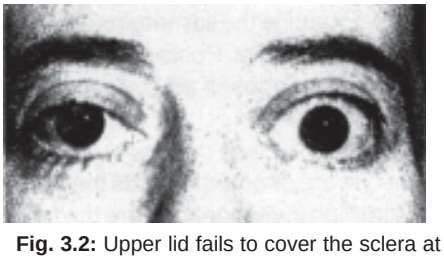


Fig. 3.2: Upper lid fails to cover the sclera at 12 O' clock position in exophthalmus (left eye)

ii. Aggravating factors like exercise
iii. Associated factors, e.g. weakness of limbs
iv. History of trauma and/or surgery
v. History of infection, e.g. trachoma
vi. Medication, e.g. long-term use of steroid.

During examination, the following causes of ptosis are to be kept in mind:

A. Congenital

Absent upper lid crease. May be associated with extraocular muscle pathology, squint, etc.

B. Acquired

i. Mechanical: Lid tumour, huge chalazion, post-trachomatous scar tissue.
ii. Myogenic: *Myasthenia gravis*, ptosis increases after the day's work or exercise.
iii. Neurogenic: Affection of oculomotor nerve, Horner's syndrome.
iv. Drug induced: Long-term use of steroid.
v. Postoperative: If large conjunctival flap is raised, e.g. after cataract surgery.

Press firmly over the eyebrows with your palm to neutralise the action of frontalis. Now ask the patient to look down. Put a scale, vertically putting the zero mark on the lowest border of the upper lid. Ask the patient to look up. Note the excursion of the lid border. Normally it is 10 mm. Compare the excursion of the other upper lid. The difference between 10 mm and the excursion of the upper lid is the amount of ptosis.

Note the movement of the eyes to detect any extraocular muscle palsy and perform cover test. Record if squint is detected.

Examine the pupil size and its reactions to light. In 3rd cranial nerve palsy, pupils will be dilated and in Horner's syndrome, pupil will be constricted. Examine the lid margins and changes in the tarsal conjunctiva. Postoperative scars and trachomatous changes, if any, are to be noted.

Investigations in a Case of Ptosis

Investigations are directed towards the suspected cause. Common investigations are the following:

i. Prostigmin test or tensilon test: To establish *myasthenia gravis*, this test is done. Atropine is to be used in prostigmin test to nullify the effect on the heart.

A clinical test for *myasthenia gravis* is the administration of a short-acting cholinesterase inhibitor, usually edrophonium chloride. A small test dose is given intravenously initially to ensure that the patient is not allergic; if tolerated a full dose of 0.2 mg/kg (maximum dose 10 mg) is given IV a few minutes later. Children weighing less than 30 kg should be given only 1-2 mg total dose. Within a few seconds, the ptosis and ophthalmoplegia improve, and fatiguability of other muscles is greatly decreased. The effects only last 1-2 min. Edrophonium should not be given to young infants because cardiac arrhythmia may result. An alternative with fewer cardiogenic side effects is intramuscular neostigmine. If the initial test of 0.04 mg/kg is negative; the infant may be retested 4 hours later with 0.08 mg/kg. A maximal effect is seen in 20-40 min. Because of muscarinic side effects, such as abdominal distention, diarrhoea and profuse tracheal secretions, 0.01 mg/kg of atropine may be given just before the neostigmine.
ii. Myography of extraocular muscle is done for progressive myopathy.
iii. Radiological investigation of chest and neck are done in Horner's syndrome.
iv. Photographic record is a must.

EXAMPLE OF PTOSIS DATA SHEET (Fig. 3.6)

	Right eye	*Left eye*
Vertical palpebral fissure	9.5	6.5
Margin reflex distance	+ 4	+ 2
Upper lid crease	8	11
Upper lid excursion	15	11

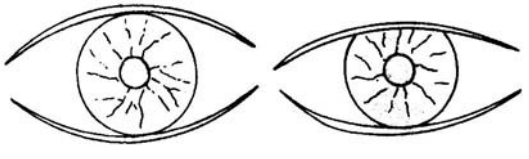


Fig. 3.6: Example of ptosis data sheet

Specific data should be recorded when evaluating ptosis patients. A drawing of the cornea, pupil size, and the position of the upper and lower eyelids, in relation to the structures is essential. Photograph of both eyes in primary position, upgaze and downgaze are very helpful in following the course of a patient with ptosis.

Vertical palpebral fissures Measurement of the vertical palpebral fissure at their widest point. The position of the lower lid as well as the upper eyelid determines its value.

Margin-reflex distance The distance from the upper eyelid margin to the corneal light reflex in primary position. The light reflex may be obstructed by the lid in severe cases of ptosis, and therefore assures a negative value. This is probably the most effective single measurement in describing the amount of ptosis.

Upper eyelid crease The measurement of the upper lid crease to the lid margin. High, duplicated, and asymmetrical creases may indicate abnormal insertions of the levator aponeurosis.

Upper eyelid excursion The upper lid excursion is a measurement of the movement of the upper lid from downgaze to upgaze. Care should be taken to minimise contributions from accessory elevators of the lids, e.g. the frontalis muscle, by fixating the brow. The amount of levator function is crucial in determining the etiology and the treatment plan.

Ancillary tests Drawings and photographs are especially helpful in documenting the eyelid contour. Pharmacologic testing, e.g. phenylephrine 2.5 per cent will stimulate the tarsal muscle (Muller's). Topical cocaine prevents the reuptake of norepinephrine from the neuromuscular synapse and confirms the clinical diagnosis of Horner's syndrome. Hydroxy amphetamine 1 per cent stimulates the release of norepinephrine at the neuromuscular synapse of the third order neurone and helps to determine the location of the lesion, causing the Horner's syndrome. Visual field testing is often essential in documenting visual dysfunction.

EXAMINATION OF THE LACRIMAL SYSTEM

HISTORY

1. In suspected cases of decreased tear secretion, following complaints should be noted carefully—redness, burning, itching and uncomfortable eyes.

   General medical history must be taken carefully, to detect rheumatoid arthritis, practolol medication, etc. Local causes like Stevens Johnson syndrome, alkali burn, etc. to be noted.
2. Watering.

EXAMINATION

1. Orbicularis function should be assessed.
2. Pressure should be applied over the lacrimal sac— reflux of pus/mucus indicates mucocele with a patent canalicular system and an obstruction in the sac or nasolacrimal duct.
3. *Slit lamp examination*
   a. Lower lid tear meniscus should be examined. Height of lower lid tear film meniscus is between 0.1 to 0.6 mm. The normal thickness is about 1.0 mm. If it is less than 0.5 mm, there is tear deficiency. In keratoconjunctivitis sicca (KCS), it may be absent or diminished.
   b. Precorneal tear film may contain mucus threads and filaments in KCS.
   c. Corneal epithelium may show filaments, interpalpebral punctate erosions (epitheliopathy) and opacification in severe cases of KCS.
   d. Position of lower lid and puncta, size of the punctal orifices, presence or absence of a foreign body or tumour should be evaluated.

      Staining with fluorescein dye makes the tear film more easily visible. It also shows areas of denuded corneal epithelium, and punctate staining of the cornea. Fluorescein stain is best seen using cobalt blue light.

4. Staining with 1 per cent Rose Bengal

In eyes with KCS, rose bengal stains the bulbar conjunctiva in the form of two triangles with their

bases at the limbus. Mucus threads and corneal filaments will be shown up more clearly by the dye. Usually, a microdrop of 0.5 to 1 per cent solution is used. As the dye is irritating, this test must be performed as the last test to avoid false reading of Schirmer's test.

5. Schirmer's Test

The paper is folded so that 5 mm of the strip lies within the lower conjunctival sac and the remaining 25 mm projects over the lower lid. The amount of moistening is noted after 5 mins. Traditionally, Whatman's filter paper No. 41 is used (Fig. 3.7).

Fig. 3.7: Schirmer's test

Test-1 It measures total reflex and basic secretion. The paper is placed at the outer 1/3rd of the lower lid. The patient is placed in a dimly lit room and instructed to keep his eyes open while gazing in the front. A value of less than 5 mm indicates impaired secretion (normal value is between 10 and 30 mm). If the wetting is more than 30 mm, reflex secretion is intact but not controlled or there is a blockage of the drainage apparatus.

Basic secretion test: This test is performed after the instillation of a topical anaesthetic. The difference between this and Test-1 is the amount of reflex secretion.

Test-2 It measures the reflex tear secretion and is performed after instilling a topical anaesthetic and irritating the anaesthetised nasal mucosa with a cotton swab. The amount of wetting is measured after 2 minutes. Reading less than 15 mm indicates failure of reflex secretion.

6. Fluorescein Dye Disappearance Test (DDT)

Two per cent fluorescein is instilled into both conjunctival sacs. Normally, in the absence of obstruction to the lacrimal drainage system there will be no or very little dye retained after 2 minutes. A prolonged retention (over 5 minutes) of dye in one eye is significant.

7. Tear Film Break-up Time

This test is performed by instilling fluorescein into the lower fornix and asking the patient to blink once, and then to refrain from blinking. The tear film is scanned by using a cobalt blue filter with a broad beam. After some time, black spots/lines indicating dry spots will appear on the tear film. The time between the blink and the appearance of the first dry spot is measured with a stop-watch. In normal eyes, the break-up time is between 15 to 35 seconds. A break-up time of less than 10 seconds is definitely abnormal.

In mucin deficiency, break-up time is abnormal but Schirmer's test is normal whereas in KCS, the break-up time may be normal or abnormal but Schirmer's test is abnormal.

8. Irrigation (Syringing)

A drop of 4 per cent lignocaine, HCl is instilled in the conjunctival sac and a straight lacrimal cannula, on a 2 cc saline filled syringe is inserted into the lower canaliculas after its dilatation by punctum dilator (Fig. 3.8, Plate 2). As the cannula is inserted deeper, an attempt is made to touch the medial wall of the sac and the lacrimal bone. The cannula can come either to a 'hard stop' or to a 'soft stop'. Hard stop is a firm feeling caused by the cannula touching the medial wall of the lacrimal sac and the lacrimal bone, and indicating that the lacrimal sac has been entered with the exclusion of a complete obstruction to the canalicular system. Now, the irrigation is undertaken. If the saline passes freely to the nose, then there is no obstruction or partial obstruction. If no saline reaches the nose then there is total obstruction. Here, the lacrimal sac becomes distended with normal saline which comes out through the upper punctum.

Soft stop is a spongy feeling which indicates that the cannula has been prevented from entering the sac by an obstruction in the canalicular system. Irrigation will not cause the sac to distend. In case of a lower canalicular obstruction, there will be reflux of saline through the lower canaliculus. Reflux through the upper puncta indicates patency of both upper and lower canaliculi but a total obstruction of the common canaliculus.

9. Examination of the Nose

It should be done, in order to determine the positions of normal nasal structure, particularly the position of anterior end of the middle turbinate, polyps or tumours.

Symptoms indicative of a lacrimal excretory system dysfunction include epiphora, punctal discharge and a mass or swelling in the region of medial canthus. Excessive lacrimation can also occur with stimulation of reflex arc, such as ocular irritation or dental, sinus and ear disease.

Primary dye test (Jones-I test) This test like DDT, investigates lacrimal outflow under normal physiologic conditions. However, it is tedious to perform and gives an abnormal result in one-third of normal patients. Fluorescein dye (2%) is instilled into the conjunctival fornices and is recovered in the inferior nasal meatus by passing a cotton-tipped wire probe into the region of ostium of the nasolacrimal duct. This manoeuvre may be facilitated by anaesthetising and shrinking the mucosa of the turbinate with topical cocaine. However, the anaesthesia may selectively mask those patients in whom hypertrophy and impaction of the turbinate are externally compressing the ostium of the nasolacrimal duct.

Secondary dye test (Jones-II test) This test can be performed either after a positive dye disappearance test or after failure to recover dye in the primary dye test. The conjunctival fornices are irrigated to remove the residual dye. After instillation of topical anaesthesia, the lacrimal sac is cannulated and irrigated. If dye is then recovered, it indicates an incomplete blockage of the nasolacrimal duct, a patent upper system, and a functioning lacrimal pump. If clear fluid is recovered in the nose, this indicates either a nonfunctional lacrimal pump or an anatomic barrier between the conjunctival fornix and lacrimal sac.

If a nonfunctional lacrimal pump due to poor lid tone is suspected, both the dye disappearance test and secondary dye test can be repeated, horizontally tightening the lid with tape at the lateral canthus, thereby augmenting the lacrimal pump.

Scintigraphy Scintigraphy using gamma ray emitting radionuclides such as technetium-99 can also be used to evaluate the physiological flow of tears. Advantages of this technique are: (a) more normal, as compared to the Jones dye test, showing complete tear flow, (b) the ability to document the examination with photography, and (c) better contralateral comparisons.

Taste tests Saccharin and chloromycetin have been used in evaluating physiological tear flow. However, the reliability of these tests has not been consistent.

Dacryocystography It can add useful information particularly when a mass (benign or malignant neoplasm or foreign body) is suspected. It is performed using an oil-based contrast medium and plain X-ray technique. Newer modifications, including image intensification and digital subtraction allow a more detailed examination.

Computerised tomography Computerised tomography is an useful adjunct, when dealing with lacrimal obstruction following craniofacial injury in congenital craniofacial deformities, or when lacrimal sac neoplasia is suspected. Particular attention must be given to preoperative identification of any abnormal position of the cribriform plate, to avoid a possible cerebrospinal fluid leak.

EXAMINATION OF ORBIT

The commonly occurring disorder of the orbit in children and adults must be considered separately before evaluating the orbital disorder. A carefully taken history goes a long way in detecting the orbital pathology. This history must include systemic, in addition to ocular.

Systemic examination must always be included in the work-up of your orbital examination. Visual acuity, ocular movement, evaluation of diplopia (if any), evaluation of fundus and a complete examination of the anterior segment are important.

EXAMINATION

A. Note the following:

1. Position of the lids and degree of closure.
2. Cornea if normal, or pathological changes e.g. exposure keratitis has already occurred.
3. Conjunctiva if chemosed, indicates increased orbital venous pressure.
4. Movement of the eyeball—which may be restricted by space occupying lesion, entrapment or neurological involvement.

B. Note the position of the eye in the orbit:

The position should be noted in three axes namely horizontal, vertical and anteroposterior. Horizontal and vertical displacement of the eye in the orbit can be evaluated by shinning a pen torch on the cornea, from the front. The anteroposterior displacement is evaluated in the following way:

1. The patient is asked to close the eyes lightly. Apply the straight edge of a scale or cardboard, to the middle points of the upper and lower margins of the orbit. The edge should just touch the closed lids over the cornea. If the eye is compressed or the edge cannot be placed — the eye is proptosed (Figs 3.9A and B).

Figs 3.9A and B: Proptosis — (A) A straight scale cannot be placed touching the upper and lower margins of orbit in proptosis. (B) A normal eye

2. Ask the patient to sit on a stool and you stand behind him. Ask the patient to fix a point above the eye level. Look down, so that you can see the tip of the patient's nose-tip. Hold the patient's head and slowly rotate it backwards. At a point, you will just see the apex of one cornea. Compare with the other cornea. The cornea of the eye visualised first is proptosed or more proptosed.
3. Perform exophthalmometry for more accurate measurement. Hertel exophthal-mometer is described here (Fig. 3.10, Plate 2). Ask the patient to stand erect with the back straight against a wall. Place the concave parts of the exophthalmometer on the outer orbital margin. The distance between the orbital margins will be read off directly from the bar reading (Fig. 3.11). This record is to be noted for future reference. The distance between the two outer margins must be constant at each reading.

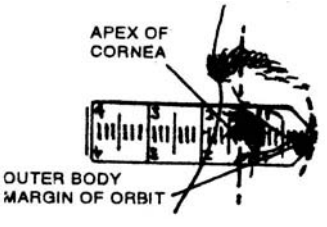


Fig. 3.11: Exophthalmometer

Now ask the patient to fixate your right eye with his left. Observe the image of the apex of the cornea in the mirror and note the reading in mm. Similarly, note the reading for the other cornea. Normal reading is between 12 to 20 mm and a discrepancy of 2 mm between the two eyes is normal.

C. Orbital pulsation:

Palpate over the proptosis. Pulsation may be visible in addition to palpability. A pulsating proptosis may be due to—carotid-cavernous sinus fistula, vascular tumour or aneurysm, or a cerebral pulsation may be felt through defect in the orbital roof.

D. Variation of degree of proptosis with change of posture:

Ask the patient to bend down the head. The proptosis increases due to orbital varix.

E. Ascertain the direction of proptosis considering all the observations made above:
Axial proptosis may be due to optic nerve lesions, inflammations like orbital cellulitis, retrobulbar haemorrhage, endocrine disorder like thyroid exophthalmos (Fig. 3.12, Plate 2).

A space occupying lesion is suspected on the opposite side of the displacement. In such a case, try to feel the mass. The consistency may provide important clues to diagnosis.

INVESTIGATIONS IN A CASE OF ORBIT

Invasive investigations like orbital venography have almost completely been replaced by noninvasive or less invasive methods in the recent past. The common investigations specific to orbit are plain X-ray, ultrasonography and computed tomography. In addition to these, specific investigation of the suspected cause is to be ordered. The opinions of otolaryngologist, neurosurgeon, endocrinologist or haematologist may be important in arriving at the diagnosis.

Plain X-ray Different important views are:

a. Caldwell view: In this posteroanterior projection, the advantages are—clear visualisation of the orbital rim and roof, greater wing of sphenoid is easily detected and superior orbital fissure is clearly visible.
b. Optic canal view: Clear visualisation of the structure.
c. Lateral view.

Ultrasonography A rapid method of investigation is B-scan ultrasonography with limitations because the sound wave cannot penetrate the bone.

Computed tomography More accurate localisation of the SOL and changes in the muscle and other soft tissue can be recorded by this method, as it provides sectional views.

a. *CAT (Axial):* The view is parallel to the optic nerve.
b. *CCT (Coronal):* The view is parallel to equator of eyeball.

USES OF CT SCAN IN OPHTHALMOLOGY

Computer assisted tomography helps in diagnosis by better visualisation of the orbit and intracranial structures and hence is rapidly replacing invasive techniques.

Principle

A large number of individual readings are taken of a collimated X-ray beam, scanning the transverse or coronal slices of the head (Fig. 3.13). The readings are then processed by a computer, which reconstructs the anatomy of the slice. Soft tissues too, are demonstrated and thus a three dimensional reconstruction is possible. Current CT scanners administer a dose of radiation of approximately 0.25 rads per scan pass.

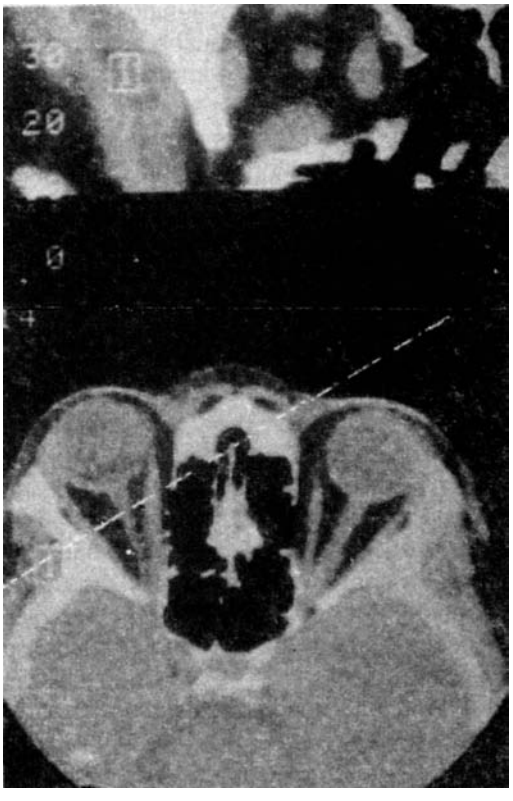


Fig. 3.13: CT scan of orbit. Top: Coronal scan Bottom: Axial scan

Technique for Orbital CT

CT examination of the orbit is done with 5 mm axial and coronal slices with the axial sections made roughly parallel to the orbitomeatal line.

Coronal scanning is performed with the patient prone and the head maximally hyperextended. A lateral scout image (digital radiograph) is used to select coronal slices as close to the true coronal plane as possible, while avoiding scanning through metallic dental work, which causes substantial detrimental artifact. Occassionally, sections at several different angles must be taken to cover the area of interest and to avoid artifacts. Coronal scanning is usually extended posteriorly to the suprasellar region, particularly when the patient suffers from visual loss or visual field defects. Inclusion of the perisellar area is also essential when an orbital lesion has an intracranial component, such as with meningioma of the sphenoid ridge. Although routine scans reliably detect the vast majority of intraorbital lesions, additional 1.5 mm slices are occassionally obtained when finer detail is required.

Coronal scan sections are indispensable in evaluation of lesions located at the inferior and superior extremes of the orbit which could be overlooked if the study were limited to the axial plane. The optic nerves, the superior and inferior rectus muscles, the paranasal sinuses, and the orbital floor and roof required coronal sections for thorough evaluation.

Many CT scanners are now capable of performing computer reformation of data from axial scanning into coronal, sagittal or oblique sections. The facility of this process varies among scanners, but it is often time-consuming and produces images of lesser quality than direct scanning, though reconstruction is invaluable in those cases in which direct coronal scanning can not be performed, such as in young children, patients with limited neck mobility or those with extensive dental work. Occassionally, a sagittal or oblique reconstructed image is useful such as when visualisation of the entire optic nerve is desired within a single section.

The need for intravenous contrast administration for orbital CT is controversial. Intraorbital fat, because of its inherent low density, provides natural contrast to the other soft tissue structures. Contrast material uniformly increases the density of all of the intraorbital soft tissue structures, but does not significantly enhance their visibility. Attempts to discriminate between lesions based on their contrast enhancement characteristics have been disappointing. However, because contrast material is necessary to evaluate the intracranial extension of orbital lesions and the sellar area, it is usually employed except in cases where the process is known to be limited to the orbits, in the posttraumatic situation where hematoma is suspected, or when contraindicated because of an allergic history, renal failure or other medical conditions.

Approach to Orbital CT Diagnosis

CT is virtually 100 per cent reliable in detecting intraorbital masses. A properly performed CT always demonstrate any focal lesion responsible for proptosis. Many other processes in addition to neoplasms may produce proptosis or other clinical findings consistent with an intraorbital mass. The majority of these also are easily recognised on CT scan. When a mass is found, careful analysis of the informations revealed by high resolution CT can usually yield at least a relatively short differential.

Lesions causing orbital mass effect usually can be divided into two groups, i.e. masses apparently arising *de novo*, and those that represent enlargement of normal intraorbital structures. Recognition that an orbital mass arises from the optic nerve or lacrimal gland, for example, significantly limits the differential possibilities. When a mass is large, infiltrating or invasive, it may be difficult or impossible to identify the site of origin.

Another classification of intraorbital masses is into intraconal and extraconal groups. With benign or otherwise well-contained masses of extraconal origin, the nearby rectus muscle or the aponeurotic cone itself can often by recognised, away from the bone, displaced inward. Two common orbital masses, hemangioma and dermoid cysts are almost invariably of intraconal and extraconal origin, respectively.

Many patients presenting with evidence of an intraorbital mass will be found to have lesions

arising in continuous structures with secondary orbital compromise or invasion. CT is of particular value in identifying and demonstrating the extent of such lesions and is often vital for directing surgical approach for biopsy or excision. In most cases, analysis of the mass itself and associated bony changes will indicate the site of origin and the nature of the lesions.

It is important to know whether an orbital process is unilateral or bilateral. Grave's orbitopathy, for example, involves both the orbits in nearly all the cases and would be the usual diagnosis in most cases of bilateral muscle enlargement. Bilateral or multicentric involvement of structures other than the muscles exclusively would suggest metastases, orbital pseudotumour or lymphoma.

The degree of enhancement in orbital masses is seldom significantly helpful in differential diagnosis. However, in cases of cystic lesions, a suggestive or even pathognomonic appearance may be seen. A capsule of higher density than the central content and/or curvilinear rim calcifications suggest a cystic lesion. In case of a cystic lesion the internal material does not change in density following contrast administration; enhancement of the capsule may occur. Dermoid cysts and mucoceles account for the majority of cystic orbital lesions. Orbital abscess is somewhat less common; hydatid cysts are also rare. The density of cyst contents may be an important clue to the diagnosis, particularly, in the case of fatty material which would suggest a dermoid cyst.

The nature of the margins of the abnormal area against the orbital fat is very important. Lesions with well-defined margins are usually benign. Vague, poorly-defined margins suggest an infiltrating process which is most often malignant or inflammatory.

The shape of a mass may sometimes be helpful in differential diagnosis, particularly, in the case of vascular lesions such as arteriovenous malformations (AVM) or varices where the tubular shape of components of the abnormality are characteristic.

Calcification within a lesions are easily detected by CT, which is far more sensitive to their presence than other radiographic modalities. Calcifications have been noted in epithelial tumours of the lacrimal gland, cavernous hemangiomas, retinoblastomas, orbital varices, within the capsule of orbital dermoids and, occasionally, in optic nerve meningiomas and gliomas. Lymphoma and metastases. On the other hand, essentially never calcify unless they have been treated. Patterns of calcification may be characterised as amorphous, focal, diffuse or peripheral (rim-like). Specific calcification patterns are discussed in conjunction with the appropriate lesions.

The effect of a lesion on adjacent bone is important to note. Frank bone destruction generally signifies an aggressive, usually malignant, process. Smooth erosion or molding of bone, especially if it results in the production of a fossa for the tumour, usually indicates a long-standing benign lesion. Certain benign lesions, particularly mucoceles, may thin bone to the point of invisibility of CT, but do not actually destroy it. The hazards of evaluating the thin lamina papyracea have been noted. Thickening of bone, and/or increase in its density, may occur with fibrous dysplasia, meningioma, chronic sinusitis and, rarely, with lacrimal gland tumours. A form of bone sclerosis is also seen in some cases of metastases, particularly, from the breast and prostate.

Integration of available clinical and laboratory information may be helpful or indispensable in constructing a differential diagnosis. The nature of the clinical presentation, a history of trauma, systemic malignancy of signs of orbital infection, as well as other clinical and laboratory data may be crucial in a given situation.

CT Scan in Orbital Disease

Optic nerve The course and dimensions of the nerve are demonstrated. The position of the eye and the plane of section are to be considered during interpretation.

a. Moderate and symmetric enlargement of both optic nerves between optic canal and the eyeball—increased intracranial pressure resulting in distension of sheath.

b. Diffuse unilateral enlargement—usually in inflammation e.g. sarcoidosis.
c. Localised areas of enlargement of nerve sheath—nerve sheath meningioma and glioma.

Extraocular muscle The size of the muscle is affected in quite a number of situations. The following clinical findings are to be considered during evaluation of the CT findings:

a. *Enlargement of muscle (Fig. 3.14):*
   Graves disease
   Orbital pseudotumour
   Congestion of orbital veins
   Neoplastic infiltrations.

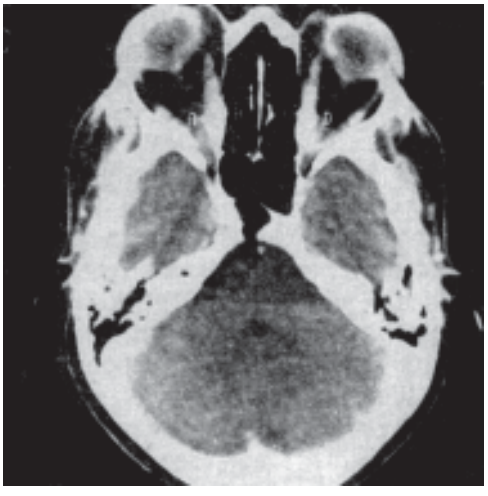


Fig. 3.14: A case of thyroid exophthalmos with muscle (MR) enlargement

b. Reduction of muscle size:
   Atrophy due to palsy-congenital or acquired secondary fibrotic changes within the muscle.

Orbital mass These are better visualised. To arrive at a diagnosis consider the following: Location and extent of the mass, density of the mass, anatomic relation with other soft tissue structures, changes in the bony orbit, changes in the para nasal sinus and middle cranial fossa.

Common Lesions

a. Cavernous haemangioma: Well delineated round or oval tumour.
b. Lacrimal gland tumour: Situated outside the muscle cone, at the upper outer angle of orbit. Attached to the lacrimal gland.
c. Lyphoma, orbital cellulitis and pseudotumours produce diffuse infiltrative lesions.

Ocular lesions Thin section reconstruction may demonstrate intraocular tumours and foreign body, vitreous haemorrhage and retinal detachment.

Intracranial Lesions of Ocular Importance

Intracranial lesions may have ocular manifestations, e.g. visual loss, visual field loss or disturbance of ocular motility.

1. *Evaluation of visual loss* The following lesions responsible can be detected:
   a. Meningioma—sphenoidal ridge and canalicular.
   b. Aneurysm—specially carotid.
   c. Tumours, e.g. pituitary tumours.
2. *Evaluation of visual field* The optic pathway including optic tract and optic radiation and the chiasmal lesions can be identified.
3. *Evaluation of oculomotor disturbance* The space occupying lesions and aneurysms can be excluded by this method.

Indications for CT Scanning of the Orbit

1. Progressive proptosis of non-thyroid origin.
2. Palpable orbital mass.
3. Progressive monocular visual loss of a non-ocular origin.
4. Monocular papilloedema.
5. Extrabulbar abnormality by ultrasonography.
6. Unexplained ophthalmoplegia.
7. Visual loss of nonocular origin, following injury to the orbital contents after an interval of normal vision, or with a nonocular visual field defect in one eye only.
8. Orbital and/or periorbital bony changes on plain X-ray such as an enlarged optic foramen, hyperostosis of the sphenoid wing, fibrous dysplasia involving the optic canal, and mucoceles.

9. Paranasal sinus disease affecting the orbit.
10. Basofrontal tumours affecting the orbit.

MRI (MAGNETIC RESONANCE IMAGING)

MRI is a noninvasive imaging technique that does not use ionising radiations and has no known adverse biologic effects. MRI is based upon the interaction of three physical components, i.e. atomic nuclei possessing an electric charge, radiofrequency (RF) waves and a powerful magnetic field. Atoms with an unequal number of neutrons and protons possess an electric charge and nuclear spin which generate a magnetic moment. These charged particles can be manipulated to interact with a magnetic field and RF waves. Under normal conditions, the charged nuclei spin about axes that point in random directions. Many elements are capable of generating MR signals. The hydrogen atom has been selected for use because it is the most abundant element in the body.

The magnetic field must be extremely powerful (2,000 to 15,000 times greater than the earth's magnetic field) to affect the spinning hydrogen protons. The strength of the magnetic field is measured in Tesla (T) or Gauss (G) units (one Tesla unit is equal to 10 Kilograms). Current magnets vary in strength from 0.1 to 1.5 Tesla units.

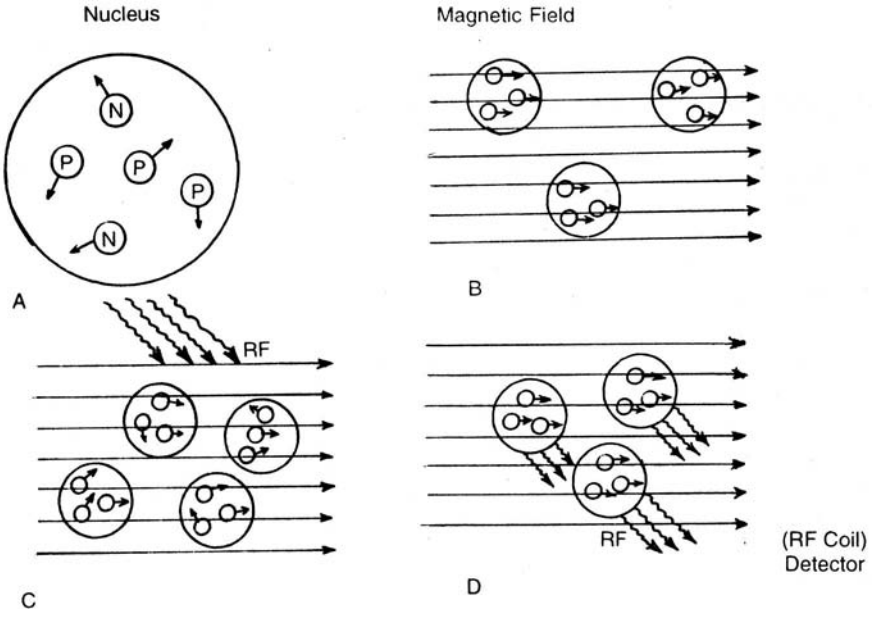
When a tissue containing hydrogen atoms is placed in the magnetic field, individual nuclei align themselves in the direction of the magnetic field. These aligned nuclei can be excited by a radiofrequency (RF) pulse emitted from a coil lying within the magnetic field. Excited nuclei align themselves against the static magnetic field and as the RF pulse is terminated, the nuclei flip back to their original magnetised position. As this occurs, the nuclei emit radiomagnetic energy that can be detected, processed, and imaged. The time it takes for this realignment to occur can be measured and is termed as relaxation time.

Various MRI parameters, provide the information needed to assess the interaction of various nuclei in their environment. Proton density is one such parameter that is determined by the number of proton per unit volume of tissue. Fat has greater proton density per unit volume than bone, and therefore has a greater signal intensity. Relaxation time of two types are another parameter. T_1 (longitudinal relaxation time) is the time required for the net bulk magnetisation to realign itself along the original axis. T_2 (transverse relaxation time) is the mean relaxation time based upon the interaction of hydrogen nuclei within a given tissue and is an indirect measure of the effect the nuclei have on each other. Each tissue has different T_1 and T_2 characteristics. Healthy tissues can have different relaxation characteristics from diseased tissue.

Compared to CT scanning, MRI has greater sensitivity to tissue contrast, which is helpful for instance in detecting demyelini-sation. MRI, however, has some distinct limitations. CT scanning gives better definition of bone when compared to MRI. The high fat content of the orbit (high signal intensity) blurs smaller structures and reduces image quality. Motion artifact is a problem because scanning times are long, and it is difficult for patients to remain motionless in the gantry for the required scanning time. Retrospective MRI image reconstruction is not yet available, so "reformating" is not possible. Ferromagnetic foreign bodies will move in the strong magnetic-field and if present in the eye or orbit, could cause ocular damage. MRI is contraindicated in the presence of ferromagnetic bodies, cardiac pacemakers, or surgical clips.

BASIS OF MR IMAGE PRODUCTION

The basis for MR image production begins at the atomic level with the conept of nuclear spin (angular momentum). Only the nuclei of atoms with an odd number of protons, neutrons, or protons and neutrons have nuclear spin. Atoms with nuclear spin include ^{1}H, ^{13}C, ^{14}N, ^{23}Na and ^{31}P. An important consequence of nuclear spin, and the foundation of MR imaging, is that each positively charged, spinning ^{1}H nucleus produces a miniature magnetic field. This miniature magnetic field can be likened to a tiny bar magnet which has both a north and a south pole. Because



Figs 3.15A to D: Physical principle of MRI (A-D). RF-radio frequency

the magnetic field has magnitude (strength) and direction (north/south) it can be represented by a vector (usually depicted by an arrow). The miniature nuclear magnetic field vector is called the magnetic dipole moment (MDM). MR images are obtained by inducing electromagnetic signals from the MDMS of ^{1}H nuclei within living tissues and then converting these signals into diagnostic cross-sectional images. Hydrogen is chosen over other atomic elements with nuclear spin owing to its relative abundance in body tissues and its effecient MR signal production (Figs 3.15 A to D).

BASICS OF ORBITAL MRI INTERPRETATION

Basic image analysis can be done with the knowledge of a few fundamental concepts.

The expected signal intensities of orbital fat, optic nerve, and brain, as well as of water, vitreous, and cerebrospinal fluid (CSF) should be known for all basic pulse sequences. Awareness of "ballpark" TR and TE numbers that produce T_1W and T_2W images is also useful, though overdependence on TR and TE numbers can lead to diagnostic error. Knowledge of the specific RF pulse sequence used is very useful in MR image analysis.

Analysis of T_1-Weighted Orbital MR Images

On a 1.5 T-magnet, a TR of 500 ms and a TE of 20 ms typically produce a T_1W image. Characteristics of a T_1W image are the following:

Bright signal intensity It is seen in orbital fat, subcutaneous tissues and to a lesser extent in bone marrow.

This is attributable to the fast T_1 decay constants of these tissues and consequent rapid T_1 relaxation.

Intermediate signal intensity It is seen in cerebral gray matter. The cerebral white matter is slightly brighter than the gray matter on T_1W images. Optic nerve and extraocular muscles also have moderate signal intensities.

Low signal intensity Low signal intensity in the vitreous and in the CSF of the subarachnoid spaces is also a sign of T_1W image. This is because of the extremely long T_1 relaxation constant of water. Fluid collections on T_1W images that contain proteins will have variable signal

intensities, depending on the amount of para magnetic effect produced by the constituent proteins.

Very low signal intensity It is found in cortical bone, calcifications and fibrous tissue. Small calcific foci may be idiosyncratically bright on T_1W images. Total signal voids are seen as a result of air in the paranasal sinuses and rapidly flowing blood in the vessels.

Points to remember

- Strong orbital fat signal can overwhelm and mask the intermediate signal intensity of small, adjacent structures.
- There is poor contrast between brighter, intermediate signal intensity structures such as the lacrimal gland and the adjacent bright orbital fat.
- T_1W images provide poor contrast between the vitreous humor and the layers of the globe, the lens, and ciliary body owing to their similar signal intensities.
- Subacute hemorrhage (more than 5 days) will appear bright on T_1W images because of the paramagnetic effects of methaemoglobin (both intracellular and extracellular) on T_1 relaxation.
- Melanin is also bright in signal intensity owing to similar paramagnetic effects.
- Excess amounts of proteins will effectively shorten the long T_1 constant of water in cysts or the vitreous, thereby producing a bright signal intensity instead of low signal intensity of water that is normally expected on T_1W images.
- Bright signal in blood vessels may be attributable to flowrelated enhancement artifact, slow flow in vascular structures after contrast enhancement, or subacute blood clot.
- Abnormal masses may have high, intermediate or low signal intensities, depending on their tissue constituents and whether an intravenous contrast agent has been administered.

Analysis of T_2 Weighted Orbital MR Images
On a 1.5-T magnet, a TR of 2000 ms and a TE of 80 typically produce a T_2W image. Characteristics of a T_2W image are the following:

Bright signal intensity It is seen in the vitreous and CSF. Fat signal intensity is less birght than on T_1W images. The amount of decreased fat brightness depends on the length of the TR. Heavily T_2W images have longer TRS and a darker fat signal (Fat may remain relatively brighter on the newer fast SE pulse sequences).

Intermediate signal intensity It is seen in the cerebral white matter. On T_2W images, cerebral gray matter now has a slightly brighter signal intensity than cerebral white matter.

Very low signal intensity It is seen in cortical bone and calcifications. Air in the paranasal sinuses, soft tissue, gas and rapidly flowing blood are characterized by signal void.

Points to remember

- Conventional T_2W images of the orbit provide less anatomic details than T_1W images.
- Anatomical detail is degraded by patient motion artifact from longer scan times of T_2W images.
- Bright signal intensity of vitreous improves visualisation of the inner surface of the globe and structures within the anterior chamber.
- Visualisation of lacrimal gland is variable and depends upon the extent to which orbital fat decreases in signal intensity relative to the gland. Sometimes, it may appear artificially bright owing to its proximity to the surface coil.
- Depending on the direction of the frequency-encoding gradient, the high and low signal bands of chemical shift misregistration artifact may obscure the posterior portion of the globe as well as the periphery of the optic nerve and extraocular muscles.
- Cytotoxic and vasogenic oedema in tissues can both produce a bright signal intensity on T_2W images because of their respective increased intracellular and extracellular water content.
- Subacute blood can be bright because of its paramagnetic effect. Hemosiderin produces

a region of extremely low signal intensity on T_2W images owing to the profound T_2-shortening effect of its large number of unpaired electrons.

- Absence of signal secondary to magnetic susceptibility artifact from ferromagnetic materials also produces a signal void with a morphologically distorted periphery.

Analysis of Intermediate Weighted (IW) Orbital MR Images

On a 1.5 T MRI unit, a TR of 2000 ms and a TE of 20 ms typically produce an intermediate weighted (balanced) image.

In these images, vitreous and CSF are less bright in signal intensity than in T_2W images. IW images can separate the low intensity lens from surrounding higher-intensity fluid, and can resolve the globe surface into at least two layers. However, there is poor contrast between the optic nerve and CSF, as well as between the lacrimal gland and neighbouring fat. Because abnormal tissue may remain slightly bright while the adjacent vitreous or CSF signal turns intermediate to low in signal intensity, the extent of abnormal tissue is theoretically better visualised on IW images. Owing to their lower diagnostic yield, IW images are not frequently used for routine orbital MR imaging.

Analysis of Fat-Suppressed Orbital MR Images

There are several categories of RE pulse sequence that can produce fat suppression. The phase-dependent chemical shift techniques have been replaced by the frequency-selective presaturation techniques. As compared to a routine T_1W image, fat-suppressed T_1W images can be recognised by noting the normal low signal intensity of the vitreous combined with the unexpectedly low signal intensity of orbital fat, subcutaneous fat, and fatty bone marrow.

Reversal of the normal signal intensity relationships between fat and intraorbital structures more accurately depicts the contour of the lacrimal gland, as well as the actual thickness of the optic nerve and extraocular muscles. A by-product of fat suppression is the reduction or elimination of the chemical shift misregistration artifact. This permits improved anatomic delineation of the posterior portion of the globe and the optic nerve, structures previously obscured by chemical shift artifact.

Fat suppressed images can be used to evaluate bright signal abnormalities on unenhanced T_1W images. Bright signal abnormalities that remain after fat suppression of non-contrast enhanced images are usually attributable to subacute haemorrhage (methaemoglobin), melanin, or fluid that contains paramagnetic protein. However, because of the absence of bright fat signal intensity, normal structures with low to intermediate signal intensity can appear artifactually bright. Routine T_1W images should always be obtained, as fatty masses may be obscured on fat-suppressed T_1W image.

Analysis of Contrast-Enhanced Orbital MR Images

Although paramagnetic agents can theoretically produce both T_1 and T_2 shortening, the effects of contrast enhancement are visualised only on T_1W images, not on T_2W images. Because regions of contrast enhancement (lacrimal gland and extraocular muscles) can be obscured on T_1W images by the adjacent bright signal fat, contrast-enhanced MR images are best produced in conjunction with fat suppression techniques.

Images produced with fat suppression and intravenous Gd-DTPA enhancement will show normal intense enhancement and excellent definition of the extraocular muscles and the lacrimal gland. This should be compared with the poor visualisation of the lacrimal glands on routine T_1W images. There is also enhancement of the ciliary body anteriorly, as well as a thin line of enhancement of the choroid posteriorly. The optic nerve does not normally enhance.

Routine T_1W images should always be obtained prior to contrast enhancement because bright signal abnormalities, such as those produ-

ced by blood or melanin, may be obscured by the bright signal from Gd-DTPa enhancement. Additionally, intraorbital low signal abnormalities on routine T_1W images that do not enhance may be poorly visualised on fat-suppressed images owing to the lack of surrounding bright fat signal. Therefore, all routine T_1W images should be carefully examined for bright signal abnormalities or potentially nonenhancing low signal abnormalities that may be missed on enhanced, fat-suppressed, T_1W images. Despite careful examination, small low signal abnormalities on T_1W images may still be obscured by overwhelmingly bright fat signal intensity, particularly when using a surface coil or when recording the image with an inappropriate gray scale or film contrast.

Use of STIR as a fat suppression technique in conjunction with intravenous paramagnetic contrast enhancement may have limitations compared to other fat suppression methods. Although STIR reduces fat signal, it may also reduce signal from contrast enhancing structures as well, as a result of a phenomenon known as negative enhancement. This theoretically could reduce the conspicuity of orbital pathology.

ORBITAL MR IMAGING PROTOCOLS

1. T_1W and T_2W axial images through the orbits using a 14 to 16 cm field of view (FOV) and 3 mm thick slices with 1 mm interspaces.
2. A similar fat-suppressed T_1W image.
3. Contrast enhanced axial, coronal and/or parasagittal oblique fat-suppressed T_1w image with identical FOVS and slice parameters.
4. Axial enhanced T_1W images without fat suppression are occassionally useful for the purpose of direct comparison to the pre-Gd T-1W images.
5. Fast scanning techniques, such as FSE and FMPIR, show particular promise in the evaluation of the orbit, especially the orbital apex.

Secondary studies are performed for specific indications. They include venography, arteriography and radionuclide scanning.

Venography

Orbital venography is occasionally of value in diagnosis and management of orbital varices and in the study of the cavernous sinus. Retardation of the flow of dye posteriorly may indicate a mass within the orbit or the cavernous sinus, or an arteriovenous fistula. Contrast material is injected into the frontal or the angular vein.

Arteriography

Conventional arteriography There is some risk of serious neurologic and vascular complications with arteriography, since it requires the injection of radiopaque dye into arteries. Retrograde catheterisation through the femoral artery is a safer technique. Arteriography should be used, only in patients with a high probability of a primary intracranial lesion or of an arterial lesion such as aneurysm. Maximum information can be obtained by the use of the following: (a) selective injection of the internal and external carotid arteries, (b) magnification (to visualise smaller blood vessels) for fine details, and (c) subtraction to eliminate bone radiographically.

Digital subtraction angiography (DSA) By computer manipulation of digitalised information, bone is subtracted from the image, thus enhancing the visualisation of vascular structures. This technique is performed by intravenous injection, and the patient needs not be hospitalised. DSA is safer than conventional arteriography, though the image is not quite as good as that produced by conventional arterio-graphy. DSA is good for following patients who need repeated arteriography.

Radionuclide Scanning

Radionuclide scanning visualises orbital and intracranial details by the external localisation of gamma ray emitting radionuclides. Vascular lesions such as carotid-cavernous fistula, can often be detected by abnormal blood flow patterns, using rapid-sequence, scanning which produces a dynamic scan. Certain tumours (particularly

meningioma) and inflammatory disorders (such as thyroid orbitopathy) produce characteristic patterns on static scans.

LABORATORY STUDIES

Carcinoembryonic antigen (CEA) It may be elevated (more than 5.0 ng/ml), in cases of metastatic carcinoma to the orbital contents.

Vanillyl mandelic acid and cystathione These may be in high amounts in the urine of children with metastatic neuroblastoma.

Thyroid function tests T_3 and T_4 should be estimated in serum of suspected thyroid related orbitopathy cases. If these levels are normal, TRH (thyrotropin-releasing hormone) test may be undertaken.

Chapter 4

Examinations of Cornea, Conjunctiva and Sclera

EXAMINATION OF CORNEA

In ophthalmology, detailed and systematic examination reveals the story of the pathology—present and past.

Cornea along with the tear film on its surface forms the first refracting structure of the eye. Its anterior surface is a reflecting structure also, and behaves as a convex mirror. The cornea acts as a very high converging lens because of its interface with air. To maintain all these properties, the surface of cornea has to be perfectly smooth and the thickness truly transparent. While examining the cornea, the tear film, the surfaces and the stroma are to be examined in detail. The examination is greatly facilitated by magnification.

BASIC INSTRUMENTS NECESSARY TO EXAMINE THE CORNEA

1. A source of light which can be focussed to a point — achieved by a good pencil torch.
2. A magnifier which may be a handheld loupe or better a binocular loupe.
3. A slit lamp biomicroscope can replace 1 and 2.
4. Fluorescein strip and rose bengal dye.
5. A small tuft of cotton to assess corneal sensation.
6. A pair of calipers to measure the diameter of cornea.
7. Keratometer and keratoscope.

The first three instruments should be used as a routine and others as and when necessary.

THE EXAMINATION PROPER

The examination is described in the following convenient steps:

1. Observation of Cornea

Ask the patient to stand in front of an open window. Compare the sizes of the cornea. Are they equal? Normal adult cornea measures 12 mm vertically and 13 mm horizontally. In microcornea, the cornea is smaller and in congenital glaucoma it is larger. Such cornea may be associated with other abnormalities of the eye. Any dense opacity of the cornea will be noted as white patch during this initial examination.

An image of the illuminated window will be formed on the anterior surface of the cornea, if the surface is smooth. Such image formation is called window reflex. The image will be distorted or absent if there is corneal oedema, scar, ulcer or xerophthalmia, i.e. absence of the smooth anterior surface. To examine the whole anterior surface, ask the patient to look at your finger while you put it in front of him and move slowly up, down, right and left. Draw one circle for each cornea on your record sheet and map the areas of irregularity (Fig. 4.1).

Placido's keratoscopic disc reveals the surface irregularities better. It is better recorded by computer aided mapping.

Corneal Topography

As the keratometer measures the central 3 mm of the corneal surface area, this is inadequate to study the corneal topography.

The estimation of central and peripheral curvatures is possible using either the placido disc, a photokeratoscope or computer-assisted topographic analysers.

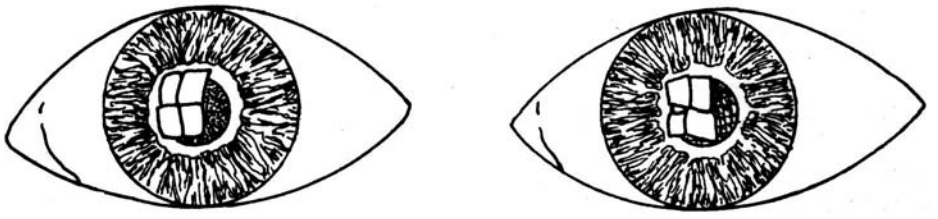


Fig. 4.1: Window reflex: Left hand figure — the image of illuminated window is clearly seen on anterior smooth convex surface of normal cornea. Right hand figure — the image of window is blurred or scarred on oedematous cornea. Note poor visibility of iris structure also

Placido disc (Fig. 4.2) It is a circular white disc with black concentric circles that decreases in size from the periphery to the centre. An observation hole is situated at the centre of the disc. The centre of the disc should be exactly on the common line of sight of the observer and the subject and also that the plane of the disc, or the surface on which the zones are drawn should be exactly perpendicular to this line. The placido disc requires to be illuminated from the external light source except in Klein's self-illuminated placido disc.

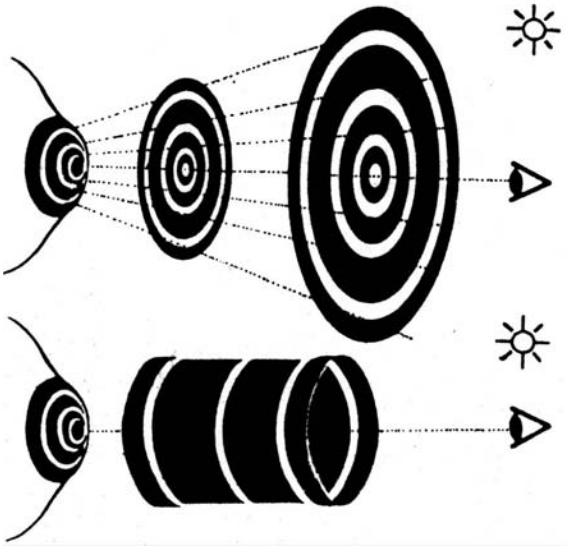


Fig. 4.2: The concentric circles of placido disc or the stripes around a tube can intersect different zones of the cornea

Photokeratoscope It has the following advantages. It allows examination of the apical cap of cornea inside the normal keratometric 3 mm reflected ring. It allows examination of the midperipheral cornea and it covers examination of 55 per cent of the total corneal curvature compared to 8 per cent with the clinical keratometer. It provides for subtle topographic shifts induced by trauma, contact lenses or corneal dystrophies and for peripheral corneal curve determination that assist in very difficult contact lens fitting.

Computer assisted topographic analysis The currently available instruments are the topography modelling system (CMS), the corneal analysis system, the computerised corneal topographer, etc.

Limitations of the keratometer

The keratometer projects a single mire on the cornea, and the separation of two points on the mire is used to determine corneal curvature. The zone measured depends upon corneal curvature; the steeper the cornea, the smaller the zone. For a 36 D cornea, the keratometer measures a 4 mm zone whereas for a 50 D cornea, the size is 2.88 mm.

The positive features of a keratometer the following:

a. Accuracy and reproducibility for measuring regular corneas within the normal range of curvatures (40 to 46 D).
b. Speed
c. Ease of use
d. Minimum maintenance requirement

The limitations of the keratometer are the following:

a. It measures only a small region of cornea; central and peripheral regions are ignored.
b. It assumes that the cornea is symmetrical; and thus averages the two semimeridians of any given meridian.
c. For corneas of different powers, it measures different regions.
d. It loses accuracy when measuring very flat or very steep corneas, particularly those in excess of 50 D.

Keratometry uses only four data points, each approximately 1.5 mm from the centre of the cornea, two on the apparently steepest axis and two on the axis 90° away.

With these limitations, it gives a reasonable estimate of central corneal curvature for normal regular cornea. However many cases with undetected pathology and virgin corneas (no previous surgery or contact lens wear) are not regular and corneas that have sustained some forms of trauma demonstrate some topographical irregularities. As a result, keratometric readings are subject to some clinically important errors:

a. Inaccurate reading for central corneal curvature
b. Incorrect or misleading dioptric measurement of 3 mm zone
c. Incorrect reading for orientation of steep and flat meridians
d. Omission of critical information regarding topography of the corneal periphery.

To understand corneal topography one must be able to evaluate central and peripheral corneal curvature. The central 3 to 5 mm region of the cornea refracts the light that provides central vision; the precise regions of the cornea responsible for this refraction are determined by the pupil size and the Stiles-Crawford effect. The corneal periphery also has an important refractive function, since it's refraction of off-axis light affects contrast sensitivity and glare, again as a function of pupil size. More importantly, the topography of the corneal periphery is a major determinant of central corneal curvature.

In interpreting these maps, it is important to recognise that the so called "hot" colours—red, orange and yellow—are steeper portions of the cornea. Green is intermediate, and cool colours—light and dark blue—are the flatter portions. It is essential to check the colour scale to see which colour corresponds to which dioptic powers and to determine the dioptic interval between colour changes. Usually the colour changes are in .5 D increments, and since 15 distinct colours are represented on the scale to the right, the entire range represents 7.5 D. The white circle in the centre of the image represents the pupil outline and the colour in that area represents the power of the central cornea.

The cursor, which is represented by a "+", is initially located at the point that represents the centre of the corneoscopic rings. The centre point is referred to as the video keratographic (or VK) axis or as the vertex normal. When viewing the topographical map on the colour monitor of the system, the cursor can be moved around the colour map with the computer mouse. The information box, which is located in the lower right corner, reports the radius of curvature (mm) and dioptric power at the location of the mouse cursor. The position with respect to the centre of the rings is displayed in radial degrees and millimetres.

Most of the maps have a grid pattern superimposed upon the image. Each square is 1 mm by 1 mm, which allows one to quickly determine how far from the corneal centre an abnormality occurs. Also note the peripheral circle marking the axes for 360°, which is especially helpful in assessing astigmatism.

The sensitivity of the map can be decreased by using larger increments on the dioptric scaling to screen for gross pathology. Conversely, the sensitivity can be increased for detecting much smaller and more subtle corneal topographic changes by decreasing the increments between colour changes. One must be aware that while zooming in for a closer look at the corneal curvature it is essential to be aware of the magnification (i.e. the dioptric power scale) or there is a chance of getting confused by clinically insignificant corneal changes.

In addition to the highly flexible "normalised" scale, where the dioptric intervals and colours

can be individualised, many systems also generate an absolute scale with present minimum and maximum values and dioptric steps. While often not as dramatic in appearance as the normalised scale, the value of an absolute scale is that the same colour and pattern always represent a specific dioptric range, eliminating the confusion that may occur if the user fails to pay attention to the colour scale.

The normal cornea is aspheric and is typically steepest centrally with progressive flattening towards the periphery. The nasal cornea is often flatter than the temporal cornea. This aspheric curvature is similar to the curvature of the long end of an ellipse. A wide variety of different corneal shape patterns can be seen in some corneas and in great frequency in corneas that have been extrinsically modified, e.g. following RK, the cornea typically flattens centrally and steepens towards periphary (Figs 4.3-4.6, Plates 3 and 4).

The corneal refractive power is determined by both its anterior and posterior curvatures. The power of the anterior surface is about +49 D and that of the posterior surface is about -6 D. Since only the anterior curvature of the cornea can be presently measured and we need to know the true corneal refractive power, a modified value for corneal refractive index is used for calculating corneal power. For most corneal measuring devices the value 1.3375 is used instead of 1.376 (the true refractive index of cornea).

Qualitative measurment of corneal topography

1. Von Loehnan keratoscope (JedMed)
2. Klein Keratoscope (Kealer's instruments)
3. Placido image
   These devices are low cost and fit for rapid use and they facilitate analysis of large regional difference in corneal curvature, such as high astigmatism following PK. However, detection of small but clinically important topographic features and quantitative measurements are not possible.
4. Corneascope (KERA): It provides photographic images of placido rings projected on to the cornea. Corneascope photographs permit qualitative analysis of corneal topography but quantitative analysis is cumbersome and accuracy is limited to + 1 to 2 D.

Computerised video keratography Computerised video keratographs (CVKs) share the following certain common features:

1. Some form of light is projected on to the cornea.
2. The modification of this light by the cornea is captured by a video camera.
3. This information is analysed by computer software.
4. The data are displayed in a variety of formats.

There are several ways to measure the corneal curvature and many of them have been utilised in currently available and prototype devices.

CVK: Placido-based devices The prevalent approach in these new devices is the use of Placido disk imaging, which is an extension of the single mire used in the keratometer. This type of imaging has the potential for excellent accuracy and reproducibility. A series of rings is projected onto the cornea, and the reflected images are detected by a video camera (The virtual image of these rings are located just anterior to the iris). Curvature data are derived from the measured distances between the rings, standard algorithms for this analysis assume that the cornea is spherical, and small errors are possible as a result.

Other algorithms for analysing ring data are now available in some devices. One of these is based on the instantaneous radius of curvature along a particular meridian and essentially utilises local changes in curvature to generate topography maps. This type of map can be particularly useful in looking at small changes in curvature at specific points on the cornea. Another new algorithm is based on the posterior focal power of the cornea and is calculated using Snell's law. It, therefore, incorporates the element of spherical aberration and more likely reflects the true refractive power of the cornea.

CVK: Other Technologies The PAR corneal topography system (CTS) uses rasterphotogrammetry, in which a two-dimensional grid pattern is projected onto the cornea and then image from a different orientation. Another method offered by

ORBTEK uses slit projection instead of placido rings. Other technologies under investigation include laser holography and Moire's fringe detection.

Normal corneal topography Using the corneal modelling system, Bogan and his colleagues provided the first classification of CVK patterns of normal corneal topography. These patterns are:

1. Round-22.6 per cent
2. Oval-20.8 per cent
3. Symmetric bowtie-17.5 per cent
4. Asymmetric bowtie-32.1 per cent
5. Irregular-7.1 per cent

As the authors point out, this classification represents positions along a spectrum of topographic patterns. Corneas classified as "irregular", undoubtedly include anomalies that have previously not been detected and can only now be evaluated using topographic images. Fewer corneas have round or oval patterns than Bogan reported, which is most likely attributable to hardware and software advances in the newer placido-based devices.

The correct alignment for video keratography is required for high accuracy and precision. The ideal corneal alignment position for vision purposes is the point where the line of sight intersects the corneal surface, the corneal sighting centre (CSC). The CSC is the corneal surface point about which light rays are centred as they enter the eye, and are refracted by the ocular interfaces, and ultimately form the foveal image. It is the primary reference point for refractive surgery in that it usually represents the centre of the area to be ablated in PRK and the centre of the area to be spared in RK. Though in order to simplify their design, present video keratographs do not align on the CSC. However, a knowledge of the alignment process is necessary in order to properly interpret more complex corneas.

The intersection of the bundle of light rays for the point of fixation with the corneal surface can be determined by using the concept of entrance pupil, which is the image of the real pupil formed by the optics in front of it, consisting of the anterior chamber and cornea. When observing a patient's eye we cannot actually see the real pupil but only its virtual image, which has a predictable relationship with the real pupil in that the diameter and position of the entrance pupil always have a constant ratio to the diameter and position of the real pupil.

The pupillary axis has been defined in several ways but is usually considered to be the line from the centre of the real pupil that is perpendicular to the corneal surface. Hence it must also pass through the centre of curvature of the corneal surface.

Astigmatism is defined as the difference in the two axes in dioptres. This definition of astigmatism depends on the implicit assumption that the cornea is symmetrical, although not spherical. Unfortunately, many corneas are asymmetrical, and the greater the asymmetry, the greater the potential for keratometric error.

Corneal topography maps the entire surface of the cornea and thus provides an extremely detailed picture of the shape of the cornea. This visual image of the cornea provides more data than keratometry often revealing that the keratometry can be misleading.

In symmetrical astigmatism conventional keratometry often describes the shape of the cornea quite accurately. However, in cases of asymmetrical astigmatism, corneal topography often yields data whereas keratometry reveals only the magnitude and axis direction. In case of an astigmatism, topography can reveal where the cornea is steeper superiorly or inferiorly. The keratometry readings do not reflect the corneal surface characteristics.

Different technologies are the following:

- Eye Sys 2000 (Eye Sys technologies)
- Eye Map EH-270 (Alcon Labs)
- Mastervue (Humphery instruments)
- ORBSCAN system (Orbtek, Inc.)
- PAR corneal topography system (PAR vision system corporation)
- Tomey Technology/Computed Anatomy TMS-1 Videokeratoscope (Tomey technology)
- Topcon Computerised Mapping System CM-10000 (Topcon)

Eye Sys System

The Eye Sys 2000 Corneal Analysis System—Eye Sys' state of the art fourth generation product—combines the technology of the previous Eye Sys products with innovative improvements.

Eye Sys System 2000 utilises a three-camera design to provide automatic focussing and in office calibration to enhance accuracy and reproducibility. It also contains a microsoft window-based software system.

A microminiaturised three-camera imaging system design provides two simultaneous views of the patient's cornea—a frontal view and a temporal view. These multiple views enable the system to accurately locate the cornea in three dimensions, automatically focus the videokeratoscopic image and then automatically correct the image processing for any images that were not at the point of optimal image focus. The front camera is aligned with the centre of the acquired ring image to provide the traditional ring mire image for the patient's cornea. The two remaining cameras are positioned on either side of the video-keratoscope to provide a simultaneous side view profile of the patient's cornea. The optical axes of the three cameras intersect at 90° at the point. Where the optimal focus of the system is achieved. In addition to automatic focus and correction capabilities, the side view profile image will allow true corneal profile measurement for the 90° meridian and sagital height measurement from corneal apex to limbus.

Video cameras use grids of discrete sensors called pixels to sense the light reflecting of all objects. The ring mires that are too small in diameter are difficult to detect due to the limited pixel resolution. Ring mires that are too closely spaced tend to blur together when reflected off distortions present with keratoconus or postsurgical corneas.

For normal corneas (42.5 D) the ring mires begin at the 0.5 mm zone and extend to the 9.6 mm zone. Within this range 360 data points are precisely located on each of the 18 ring edges (6480 data points) for accuracy over a wide range of corneal curvatures and pathologies.

The system 2000 provides a series of comprehensive diagnostic and surgical analysis displays, i.e. the "Holladay diagnostic summary" and the "STARS display". In addition to standard topographic data report formats it provides diaplays such as the Tangential, High resolution absolute, Adjustable normalized, and Difference map displays.

Holladay Diagnostic Summary (HDS) (Fig. 4.7, Plate 5) HDS provides the clinician a single report that contains informations about the following:

1. The true refractive power of the cornea at every point
2. The shape of the cornea compared to normal at every point
3. The optical quality of the cornea at every point
4. Fifteen specific corneal parameters, such as effective refractive power used is IOL calculations, to quantitatively describe the cornea.

Maps in general

The "key" giving the value for the color "green" and the colour "step" size is in the upper left or upper right cornea of each map. The black mark at the centre of all maps is the centre of the rings. It is often referred to as vertex normal since the reflected image must be perpendicular at this point. The small white circle is the pupil centre. The average diameter of the medium white circle is 3 mm and that of the large white circle is 6 mm. The actual shape of the white perimeter is identical to the shape of the patients actual dilated pupil at the time of the photograph. The 3 and 6 mm pupil perimeters are present on every map because they explain the visual changes of that may be a function of pupil size. The white reference grid is in 1 mm increments. The black numbers around the large black circle are the axis of the semimeridian.

Power map: The refractive power of cornea increases as we move toward the periphery of the cornea. The "true" refractive power map of a spherical surface should not be a single colour over the whole surface, but should show a gradual increase in power toward the periphery. This

phenomenon is called spherical aberration. The normal corneal radius of curvature flattens towards the periphery by about 7 per cent by 5 mm correcting about one half of the eye's total spherical aberration. The remaining spherical aberration is corrected by the crystalline lens which is an aspheric lens and has a higher index of refraction in the centre than at the periphery.

Refractive Map Standard Scale: The refractive power map on the standard scale is the map on the upper left of the HDS. The range is the same as in a standard manual keratometer (From 37 to 51 D), in 1 D increments. Green, the central colour is always 44 D and is the average central corneal power. As this scale is always the same, it is quickly revealed whether the central cornea is very steep (towards red) or very flat (towards blue). The normal cornea will increase by about 3 D at the periphery and should, therefore, change by three colours towards the red along any semimeridian.

Refractive Map Auto Scale: It is the map on the upper right of the HDS. It displays the same data as the standard scale, but chooses the range of powers and step size to utilise the 15 colours for the best visual display. The exact value for green and the step size are shown in the key at the top of the map. The step size can be of 0.25, 0.50, 1.00 or 2.00 D, whichever value best displays the data.

Profile Difference Map: It is on the lower left of the HDS. This map compares the shape of the patient's actual cornea to the "normal" aspheric cornea. The normal aspheric cornea has an asphericity of -0.26, that means it becomes flatter than a sphere as we move towards, the periphery, sometimes referred to as a "prolate" surface since the central curvature is the steepest. Using the patient's central corneal power and an asphericity of -0.26, the theoretical refractive power at every point is calculated. The actual refractive power at every point is then compared to the ideal aspheric cornea. The difference at every point is then plotted, in dioptres on the map. At any point, if the patient's cornea is steeper than the normal aspheric cornea, then the difference is plus and is towards the red. If the patient's cornea is flatter than the normal aspheric cornea, then the difference is negative and is towards the blue. The scale is always in step sizes of 0.50 D and the range is from -3.50 to +3.50 D. Green indicates that there is no difference between the patient's cornea and normal.

[The profile difference map correlates well with the red reflex with retinoscopy or the distant direct ophthalmoscopy because the shadows seen in the retinoscopic reflex, such as with keratoconus, are due to irregular astigmatism, that cannot be totally neutralised with a spherocylindric refraction. Pattern seen with the retinoscope such as scissoring, radial astigmatism and spherical aberration will appear the same on the profile difference map.]

This map is especially helpful in the diagnosis of corneal diseases in which the cornea changes its overall shape, such as with keratoconus, keratoglobus and pellucid marginal degeneration.

Distortion Map: This map is on the lower right of the HDS. It shows the optical quality of the cornea at every point. The distortion is mapped using Snellen's lines of visual acuity ranging from blue (20/16) to red (20/200). Green is 20/20. The map assumes the best spherocylindric correction in place, grades the optical distortion in Snellen's equivalents, then plots the appropriate colour at every point. This map helps in correlating visual performance and optical irregularities in the cornea (In anterior membrane dystrophy, the refractive power maps and the profile map may be completely normal, but the distortion map usually shows many areas of optical irregularity documenting the reason for poor vision). Serial maps at different times of the day or over several days can document the fluctuation in optical quality of the cornea, and consequently, the fluctuation in vision. Optical distortions of cornea outside the 3 mm pupil zone should have very little effect on visual performance, except when the pupil is dilated.

Corneal parameters for 3 mm pupil

There are four columns of corneal parameters at the bottom of the HDS. These values are helpful

when quantitative parameters are necessary to describe the cornea, such as with IOL calculations and keratorefractive procedures.

Column 1: Refractive power measurements

a. Steep RP (steep refractive power) is the strongest refractive power in any single meridian of the cornea. The refractive power is given in dioptres followed by the axis of the meridian. The system uses all points within the 3 mm pupil zone to find the meridian with the strongest refractive power, not just the values along the 3 mm perimeter.
b. Flat RP (flat refractive power) is the weakest refractive power in any single meridian of cornea. These two meridians may not be necessarily 90° apart. If they are not 90° apart, then there is oblique irregular astigmatism and this condition cannot be fully corrected by spherocylindric lenses.
c. Total astigmatism is the difference between steep RP and flat RP, given in plus cylinder and therefore referenced at the steep RP.
d. Eff RP (effective refractive power) is the refractive power of the corneal surface within the 3 mm pupil zone. This value is usually known as the spheroequivalent power of the cornea within the 3 mm pupil zone. This values should be used for the power of the cornea in IOL calculations as well as keratorefractive procedures. It is specially helpful in corneas with irregular astigmatism, such as keratoconus, penetrating keratoplasties, and corneas that have undergone keratorefractive procedures.

Column 2: Simulated keratometry measurements
This is primarily for historical reference and for comparison with standard manual keratometer.

a. Steep sim K (steep simulated K-reading) is the steepest meridian of the cornea using only the points along the 3 mm pupillary perimeter, not the entire zone.
b. Flat sim K (flate simulated K-reading) is the flatter meridian of the cornea using only the points along the 3 mm pupillary perimeter. As with standard keratometer, these two meridians are forced to be 90° apart.
c. Delta K is the difference between the steep sim K and the flat sim K given in dioptres at the axis of the steep sim K.
d. Avg sim K is the average of all the simulated K's within the 3 mm pupil zone.

The discrepancy between the eff RP and the avg sim K is another measure of the degree of irregular astigmatism. Although the eff RP should always give a more reliable value for the corneal power than the avg sim K, the discrepancy indicates that one should expect a higher degree of variability in the results of an IOL calculation than with a normal cornea.

Column 3: Pupil parameters and regular astigmatism The system detects the perimeter of the pupil at the time of the photograph, then calculates the centroid of the pupil.

The following three white perimeters are shown:

i. a very small one with 0.2 mm diameter, the same shape as the original pupil, at the centroid of the pupil
ii. a medium one with 3 mm diameter
iii. a large one with 6 mm diameter.

The exact shape of these larger perimeters are also the same as the original pupil diameter at the time of the photograph. If no pupil is detected by the system, small, medium and large circles are shown and centred at the nominal decentration of 0.2 mm out (temporal) from the centre of the map. "No pupil" will be reported when this situation occurs. When a pupil is detected, the relationship of the centroid of the pupil to the centre of the map (black mark) is then determined.

a. H pupil dec (horizontal pupil decentration) is the horizontal distance in mm from the centre of the map to the centroid of the pupil, where "out" (temporal) means the pupil is out with respect to the centre of the map and "in" (nasal) means the pupil is in with respect to the centre of the map. This value is commonly referred to clinically as angle kappa, and is normally about 0.2 mm out in the human.
b. V pupil dec (verical pupil decentration) is the vertical distance in mm from the centre of the map to the centroid of the pupil, where "up"

(superior) means the pupil is up with respect to the centre of the map and "down" (inferior) means the pupil is down with respect to the centre of the map. The nominal values for the human is almost zero.

c. Avg pupil dia (average pupil diameter) is the average diameter of the pupil at the time of the photograph. As the photography are done under bright light conditions, without dilation, the pupil diameter is usually less than 3.0 mm.
d. Reg astig (regular astigmatism) is the amount and axis of astigmatism that can be neutralised with a spherocylindric correction. This cylinder and axis are very helpful in refracting patients with irregular corneas. The programme finds the best fit power and axis of the cylinder that best corrects the irregularity. The reg astig will always be less than or equal to the tot astig, because the tot astig also includes irregular astigmatism, not just regular astigmatism. The disparity in the two values, is therefore, a measure of the degree of irregular astigmatism.

Column 4: Miscellaneous measurements These are as follow:

a. Asph (Q): Most investigators use the asphericity (Q) in the conic equation to describe the corneal asphericity. The normal value is -0.26, indicating that the normal human cornea flattens by about 7 per cent in its radius of curvature compared to a sphere at a distance of 5 mm from the centre. The asphericity for a sphere would be 0.00 and, if the cornea flattens more than the normal asphericity, then the magnitude would exceed -0.26.
b. CU Index (Corneal uniformity index): It is a measure of the uniformity of the distortion of the cornea within the 3 mm pupil expressed as a percentage. A CU index of 100 percent means that the optical quality of cornea is almost perfectly uniform over the 3 mm pupil. A CU index of 0 per cent indicates that the optical quality of cornea is very nonuniform over the 3 mm pupil. A CU index is useful in the differential diagnosis of corneal pathology where generalised or localised characteristic patterns are present. Normal values usually exceed 80 per cent.
c. PC Acuity (predicted corneal acuity): It provides a single value in units of Snellen's acuity of the optical quality of cornea within the 3 mm zone. The PC acuity estimates the predicted acuity if the cornea is the limiting factor in the visual, system. It can be very useful in differentiating corneal disease from lenticular diseases.

Together, the CU index and the PC acuity are very helpful in characterising corneal abnormalities and monitoring changes over time. These values should correlate visually with the appearance of the central 3 mm zone on the distortion map, but the programme takes into account other parameters, such as Stiles-Crawford effect, which makes visual estimation only approximate.

Stars Display

This was specifically designed for the refractive surgeon to provide a retrospective view of cornea to help analyse surgical results and the healing pattern caused by refractive surgery. The STARS display is a five-map display containing a preoperative examination and two postoperative examinations on the top row and two difference maps on the bottom. The operator selects the preoperative, postoperative, and follow-up examinations and the STARS display calculates the corneal changes caused by surgery (preoperative to first postoperative) and the changes occuring between the postoperative examinations.

A single standard scale used for the preoperative and the two postoperative examinations provides a serial view of the patient's corneal changes. The corneal changes from the preoperative examination to the first postoperative examination (surgical change) and from the first postoperative to the second postoperative examination (healing changes) are calculated and displayed as two subtracted difference maps. The scales from difference maps are centred on the mean difference in central keratometric values for each pair of examinations, providing maximum resolution for analysing the changes. A synchronous

mouse cursor provides precise point to point comparisons of corneal power and curvature.

High Resolution Absolute Scale It provides a consistent means for analysing data across numerous corneas. This scale combines colours and patterns to form a standard colour scale ranging from 35 to 52 D in clinically significant 0.5 D increments. Using the high resolution absolute scale, the clinician quickly performs true colour-coded diagnoses and comparisons between corneal topography maps

Adjustable Normalised Scale It automatically adjusts for each cornea under examination by centering the scale on the mean corneal curvature and adjusting the increments to include the entire range of corneal curvature. The normalised scale defaults to 0.5 to 1.0 or 2.0 D steps depending on the cornea's curvature range. The step size and centre value can be easily modified, allowing the operator to zoom in on a particular area of curvature for a more precise study.

Tangential colour map The software provides two measures of the cornea's radius of curvature to allow clinicians to choose the most appropriate colour map for the cornea being analysed. The radius of curvature most often used for representing corneal topography, is known as the axial or sagittal radius of curvature. This measurement is used for generating the normalised and high resolution absolute scale colour maps. The alternative measurement, the tangential radius of curvature, is depicted in the tangential colour map.

The axial radius may be presumed as the steel ball equivalent radius because the radius at any corneal point would be equal to that of an equivalent steel ball whose centre lies on the videokeratograph axis. As the equivalent steel ball should always be centred on the axis of the videokeratograph, the axial radius of curvature is axis dependent. The axial radius of curvature is required for evaluating the centre cornea whereas the tangential radius of curvature is required for the peripheral zone of irregular corneas.

The tangential radius of curvature is not axis dependent since it reads directly as though the videokeratograph was realigned for each point on the cornea, allowing the tangential colour map to give more details about the true peripheral corneal shape. Using the tangenital colour map to obtain more detailed information regarding true corneal shape is particularly helpful when analysing keratoconus and postsurgical cases.

Difference Maps It is a mean to track changes in corneal topography over time. Single and dual difference maps provide this capability by displaying the serial examinations and a subtracted change map. Thus, changes in pathology and postsurgical cases can be easily documented.

Customised Displays and Reports Data display screens can be modified while examining without requiring to memorise keyboard function keys. To modify the screen, the operator selects the display options button from the bottom of the display screen. From the display options screen, the operator can change the map type, the selected examination, the map layers or the colour scale parameters. Customised displays and reports along with the personalised examination protocols help ensure that the clinician gets the desired patient data.

Multi-map comparison tools It allows the examiner to perform point-to-point comparisons of corneal topography between serial colour maps and difference maps by including a cursor box in the bottom right corner of each map. The cursor box contains details about the precise curvature, power and location of the cursor for each map on the screen.

Accuracy and Reproducibility

1. It allows permanent focus and corneal apex position verification by saving the side view profile image. As the operator verifies and permanently documents the quality of each examination, the quality of a topographic examination is guarnteed.

2. It utilises ring edge detection when processing corneal topographic data because the sharp contrast (black/white) on the ring's edge can be located much more precisely than the ring's centre. The precision of edge detection ensures greater accuracy when measuring corneal shape.
3. The operator can detect and remove artifacts caused by eyelash shadows or corneal scars to prevent erroneous data from appearing in the corneal power maps.
4. This system can be calibrated using a set of test objects ranging in curvature from 37 to 55 D. A push of a single button can automatically focus, capture, and process several images for each calibration surface while in perfect focus as well as while too far in and too far out of focus.

VIDEO KERATOGRAPHY

2. Examination of the Cornea Under Magnification

Take the handheld magnifier or loupe, between your thumb and forefinger. Examine the right cornea with your right eye and left cornea with your left eye. Put the loupe close to your eye. Move slowly to the cornea to be examined. Shine a light (e.g. pen torch) focussed to a point on the cornea. Anterior surface will be focussed first, as you move closer. The posterior surface, iris and lens will come to focus gradually. Examine the conjunctiva and lid margin also in the same way. These structures too may provide important clues to corneal disease. Note the following: Foreign body, opacity, vascularisation, deposition of pigment, oedema, epithelial defect, deposit in anterior chamber, congestion of conjunctiva and any abnormality at limbus.

3. Examination of Corneal Sensation

Take a tuft of cotton wool and draw it into a fine thread containing a few fibres only. Ask the patient to look ahead. With the forefinger and thumb of one hand lightly support the lids to help keep open. Bring the wisp of cotton from the temporal side to touch the cornea (Fig. 4.8, Plate 5). Do not touch the eyelashes. If the corneal sensation is good the patient will blink as soon as the cornea is touched. The movement of the lids will be felt by your fingers and seen by your eyes. In the event of reduced corneal sensation, a longer segment of the cotton fibre will have to touch the cornea to make the eye blink and in the event of complete loss of sensation, the blink will be absent. Quantitative measurement of the corneal sensation is possible with aesthesiometer, which uses a nylon thread, the length of which can be measured to give an indication of degree of loss of sensation.

Corneal sensation is diminished in fifth cranial nerve pathology, viral keratitis and surgical incision on cornea, leprosy, post-penetrating keratoplasty.

Corneal Aesthesiometry

Currently used aesthesiometers are Cochet and Bonnet's improvisations of Boberg-Anaesthesiometers based on the fact that the length of the thread used to check the corneal threshold is inversely proportional to the force produced when the thread is applied to the cornea.

There are two models of the Cochet and Bonnet aesthesiometer. The first one, equipped with a nylon monofilament of 0.08 mm diameter, produces pressures ranging between 2 and 90 mg per 0.005 mm. The second one, using a nylon monofilament with a diameter of 0.12 mm produces pressures ranging from 11 to 200 mg per 0.0113 mm. The end surface of the nylon thread covers 4 to 10 corneal epithelial cells and thus stimulates one sensitive nerve unit.

The more recent aesthesiometers are those of Shirmer, Larson and Draeger. The latter is an electronic optical device, first fixed on a slit lamp and later built as a portable instrument.

Measurement by Cochet and Bonnet aesthesiometer: The subject fixates a point in front of him while the observer moves the nylon monofilament perpendicularly towards the cornea until the nylon thread begins to bend. The threshold is defined by the thread beginning to bend. The threshold is defined by the length of nylon thread necessary to obtain a response in 50 per cent of the number of stimulations.

Corneal sensitivity is greatest at the apex and least at the superior limbus. The lowest value measured is in the morning whereas the highest in the evening. It is reduced in congenital disorders such as congenital trigeminal anaesthesia, congenital hypoaesthesia, and corneal dystrophies and a variety of acquired disorders such as diabetes, herpes simplex keratitis, neuroparalytic keratitis, leprosy, Adie's tonic pupil, *myasthenia gravis* and toxic injury. Surgical procedures such as limbal corneal surgery, and retinal reattachment surgery can also induce a reduction in corneal sensitivity. Contact lens wear and laser retinal photocoagulation are some other causes. Topical beta blockers, atropine and topical anaesthetics also decrease corneal sensitivity temporarily (Becomes normal on discontinuation of the drug.

4. Dye Test

This test is done when an epithelial defect is suspected. Fluorescein dye stains the epithelial defect and rose bengal stains devitalised tissue.

a. *Fluorescein dye (sodium fluorescein) test:* Ask the patient to look down and touch the upper sclera with a fluorescein strip (Fig. 4.9, Plate 5). Ask to blink a few times to spread the dye evenly on the cornea. Inspect the cornea with a magnifier (if 'cobalt blue' filter is used fluorescein stains in minute quantities are also visible) and light, preferably blue light. The margin of the defect will become prominent. The epithelial defect will be seen as dark green on bluish green background (Fig. 4.10, Plate 6).

   Seidel test When a corneal perforation is suspected, the applications of fluorescein can demonstrate the leakage of aqueous humour from the anterior chamber. The moistened tip of a fluorescein strip is applied directly to the suspected site of leakage. Then if the aqueous is indeed flowing, it dilutes the applied fluorescein which is seen being washed down the surface of the cornea.

b. *Rose bengal dye test* Rose bengal may not be tolerated by some patients due to its irritating nature. Irrigate the cornea and conjunctival sac with normal saline. Mop up the excess from the lids. Wait for a while. Put one drop of 2 per cent rose Bengal dye in the conjunctival sac. Ask the patient to close the eye for a while. Examine the cornea with a magnifier. The devitalised tissue, mucus strands and debris will be stained. Ask the patient to blink; the corneal defect will not move but the mucus and debris will move. Note if there is punctate spots on the cornea or excess mucus. Multiple punctate spots indicate drying of cornea as in early keratoconjunctivitis sicca or toxic epithelial keratopathy. Excess mucin is seen in allergic disorder, e.g. vernal conjunctivitis (Fig. 4.11, Plate 6).

   Corneal staining Fluorescein and rose bengal are the most common dyes used to evaluate the ocular surface. While both dyes can stain living cells, rose bengal does so more effectively and is intrinsically toxic. A healthy tear film blocks rose bengal staining of healthy and damaged cells. The absence of precorneal tear film in keratoconjunctivitis sicca helps rose bengal staining in this disorder. Cell degeneration or death increases membrane permeability to both dyes, but rose bengal diffusion into the stroma is much less. It is used for the evaluation of keratoconjunctivitis sicca, the interpretation of epithelial dendrites and dysplastic or neoplastic lesions. Fluorescein staining of healthy cells is limited, but fluorescein diffuses rapidly into the intercellular spaces or stroma when disruption of cell—cell junctions occur. This diffusion properly necessitates the need to examine the cornea immediately after application of fluorescein. Minute details of fluorescein staining may be lost within 1 to 3 minutes. Epithelial permeability increases in diabetes mellitus, and with some medications and also in cell degeneration and cell death. These properties of fluorescein dye makes it useful in various forms of epithelial defects, in assessing precorneal tear film, in contact lens fittings, in detection of aqueous humor leakage and in measuring epithelial and endothelial permeability.

A very small amount of concentrated dye produces much better diagnostic help as full drop may overwhelm the cornea and mask subtle findings. For this reason, fluorescein or rose bengal strips are more useful. Placing a small drop in the proximal end of the strip and letting it run down to the end gives a small but highly concentrated volume of corneal stain.

"Staining" can be differentiated from "pooling" by the fact that "pooling" occurs in a depressed or irregular area of cornea. Pooling can be distinguished from staining by touching a wisp of cotton to absorb the fluorescein tear film from the area concerned or by irrigating it with some solution. If the epithelium is intact, the pool of fluorescein will be removed and no staining of the base is noticed.

Characteristic corneal staining pattern is noticed with corneal infections, inflammations, toxic changes, degenerative changes and allergic conditions. Staining may be diffuse, focal or regional depending on the etiology, e.g. a linear staining in the upper one third of the cornea is seen with a foreign body on the superior tarsal conjunctiva and a staining of superior bulbar conjunctiva is seen in superior limbic keratoconjunctivitis (Fig. 4.12).

Negative staining refers to an elevated or irregular area of the cornea with intact epithelium in which the normal fluorescein tear film quickly dissipates. These patterns have both diagnostic and therapeutic importance in cases of recurrent corneal erosions. Negative staining may also demonstrate elevated areas in the cornea such as scars or Salzman's degeneration.

Fluorescein staining techniques have been used to measure therapeutic responses. Twenty-four hours after intracanalicular collagen implantation, mean corneal fluorescein concentration is significantly greater.

c. Fluorophotometry Fluorophotometers are used to measure fluorescein concentration in the corneal stroma and the aqueous. In the peripheral cornea, fluorescein enters the corneal stroma directly from the limbal vessels but in the centre, the dye is transferred exclusively from the aqueous across the endothelium and thus measurement of its concentration gives an indication of permeability of the endothelium. Fluorescein can be ingested (10% fluorescein solution — 5 mg/kg body weight), injected intravenously or driven into the corneal stroma from the surface by iontophoresis.

Tear film evaluation in dry eye Dry eye is caused by a group of pathological states of different aetiology. The diagnostic method should be the most suitable one for the particular disease and supplemented by other tests. Dry eyes can be classified in the following categories:

Due to aqueous deficiency These cases are fast diagnosed by Schirmer's test, tear flow and assays of lactoferrin and lysozyme. Supplementary tests should include tear film break-up time estimation and staining methods.

Due to mucin deficiency These cases are best deteched by conjunctival impression cytology or biopsy. Slit lamp examination is also helpful.

Due to lipid abnormality These cases should be examined by slit lamp and tear film break-up time should be estimated.

Lid surfacing problems These cases are diagnosed by careful slit lamp examination and vital staining of marx line and meibomian glands.

Epitheliopathy This is detected by staining of corneal and conjunctival epithelium.

The common symptoms associated with dry eye vary from mild uneasiness to severe pain. Usually the symptoms are more disproportionate to the signs. Red eyes, photophobia, foreign body sensation, itching, blurring of vision, tearing, discomfort, grittiness, burning and pain are common symptoms. There may be difficulty in keeping the eyes open and difficulty in reading because of eye discomfort. Situations decreasing the blink rate such as prolonged work at a computer terminal, television watching or exposure to dry air currents during automobile trips worsen the symptoms. Drugs for allergies, common colds, sinus problems and psychotropic drugs or sleeping medications can affect the tear

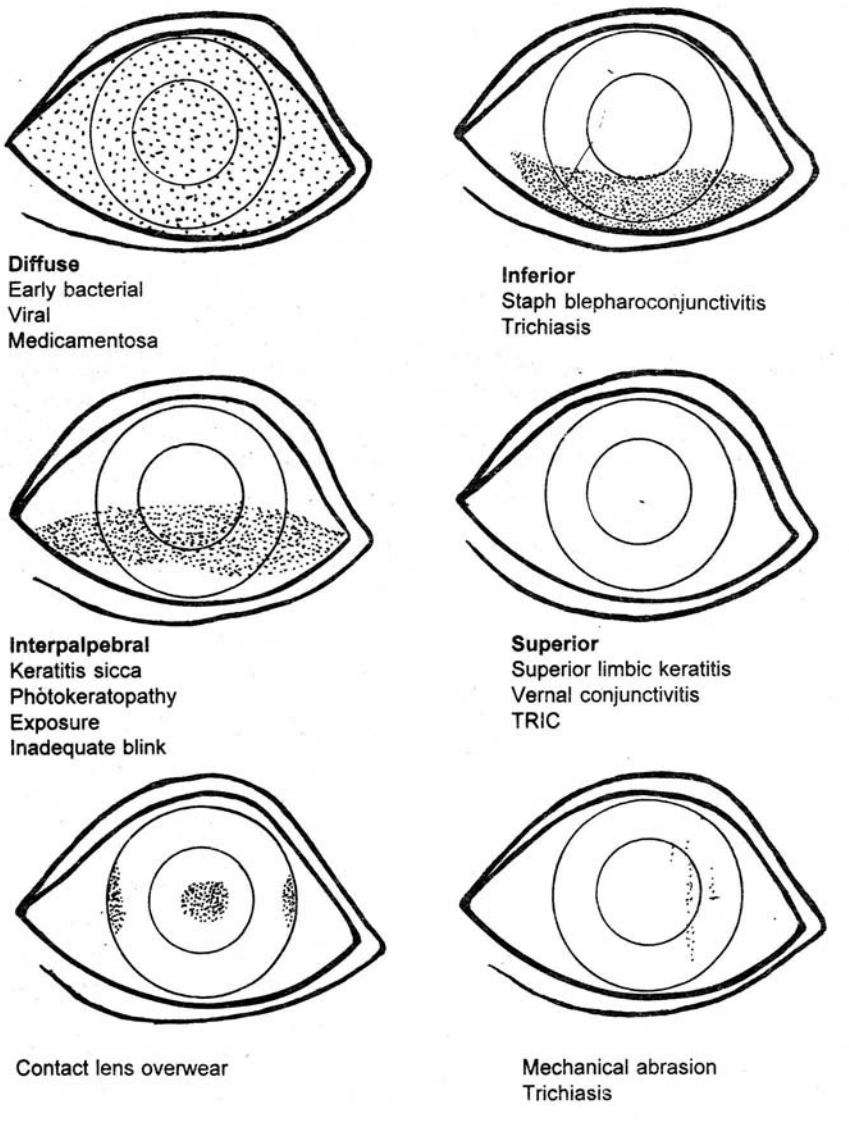


Fig. 4.12: Staining patterns of cornea and conjunctiva in different diseases conditions

film adversely and infrequent blinking in parkinsonism or Graves' disease may lead to tear film problem (Table 4.1).

Peopla who live in high altitudes and those who fly frequently in air planes may have more trouble, because the moisture in the air is low. Also those living in smoggy cities or those who work around dust and chemicals may have more difficulty. Contact lens wearers have some special problems related to dryness and irritation. Soft contact lenses particularly have a high water content and act like small sponges that soak up the tears.

Table 4.1: Drugs with potential dry eye side effects

Categories	*Generic names*
Decongestants	Phenylephrine
	Phenyl propanolamine
	Hydroxyamphetamine
Antihistamines	Diphenhydramine
	Chlorpheniramine
	Dimenhydrinate
Oral Contraceptives	Estrogens
	Progestins and Combinations
Anti-acne medications	Isotretinoin
	Tetracycline
Muscle relaxants/ tranquilisers	Medprobamate
	Chlordiazepoxide
	Diazepam

In general survey of the external eye following findings must be noted, i.e. Any redness, any difference in lid position or gloBe height, any variation in lid movement.

Lid margin and disarray of lashes indicate blepharitis which may adversely affect the tear film. A difference in position of the upper or lower lid margin suggests the possibility of lid laxity or tension from a forniceal or orbital lesion that may affect the movement of the eyelids and secondarily the tear film. Any blinking difficulty may be due to partial facial nerve paralysis (Bell's palsy or intracranial tumour). Temporal injection of conjunctiva in both the eyes may indicate thyroid ophthalmopathy.

Inferior marginal tear strip Inferior marginal tear strip should be examined by using the over head illumination of the examining room. This technique allows examination without stimulation of reflex tearing (by the strong light of a slit lamp). The size of the inferior marginal tear strip is characterised as deficient, slightly deficient, normal or enlarged. It is visualised at the juncture of inferior lid margin and the globe. A normal inferior marginal tear strip is 1 to 2 mm above the lid margin. It has a concave anterior surface. An enlarged strip will have a convex surface and rise 2 to 3 mm above the lid margin before overflowing. The deficient inferior marginal tear strip appears absent with little evidence of tears in the juncture between the lower lid and the globe. Instead, a notch appears at the juncture with minimal or no tears occupying the space between the rounded posterior surface of the lower lid margin and the conjunctival or corneal surface. Presence of debris in the tear film and mucous strands are suggestive of abnormal mucous in the eye.

Fluorescein staining Fluorescein is instilled by moistening a fluorescein strip with a drop of non-preserved saline and touching the inferior palpebral conjunctiva with it only once. The fluorescein will be illuminated with the cobalt blue light when the tear film is of adequate quantity to ionise the fluorescence. A dry eye do not have adequate tear to ionise the fluorescein and the ocular surface takes a dark orange appearance. The length of time and difficulty one has in getting the fluorescein to be illuminated, indicate the availability of reflex tears from the lacrimal gland. Fluorescein is highly water soluble and is negatively charged. Because of its polar character it cannot penetrate an intact epithelial barrier. It can, however, diffuse freely in the corneal stroma and can stain it only in areas where cornea is devoid of epithelium. While using fluorescein to detect epithelial defects in dry eyes care must be taken to differentiate between staining and pooling. The pooling is a collection of the dye in localised pockets of the corneal epithelium formed because of surface irregularity. After instilling fluorescein in the conjunctival sac the eye should be irrigated adequately (until the irrigating fluid is clear) to wash out any of the dye pooled so that only the dye diffused into the stroma can remain.

Break-up time (BUT) The test must be performed after the patient has been free of exposure to drops containing preservatives that affect the surface resistance of the tear film and the resting value of the tear film break-up time. After instilling fluorescein using only the non-preserved saline, the patient is asked to blink and hold the eyes open for at least 10 seconds. The tear film is observed in an area apart from any fluorescein

staining; the time taken by the tear film to thin and break-up, causing a dry spot to appear, is noted. The dry spot appears black against the green tear film. The time usually varies from 2 to 3 seconds with repeated readings. The average of three readings are taken. Normal is considered 10 seconds or greater; abnormal is less than 10 seconds. An abnormal tear film break-up time indicates abnormal wetting of the cornea and mucin deficiency. Fixed areas of drying should not be taken into consideration because they may represent non-wetting areas due to surface irregularity. It has been suggested that fluorescein itself may affect the stability of the tear film and "non-invasive" techniques of BUT has been tried by viewing the specular image of a reticule projected on the tear film. BUT estimations by this method have given larger values.

Examination of the meibomian glands The meibomian glands deliver lipid secretion which spread over the surface of the tear film and retard the evaporation of its aqueous component. Inspecting the meibomian gland orifices in the lid margin and placing gentle pressure on the lid against the globe will indicate how freely these secretions are flowing from the gland. Few glands are almost always occluded and do not yield secretions when pressed with the fingertips against the globe. Normally the secretions are serious whereas in lid diseases they are thick, white and viscous. Erythema of the lid margins and/or lashes in disarrahy along with plugging of the meibomian glands indicated more severe forms of lid disease and are associated with an abnormal tear film. Trans-illumination of the tarsal plates is sometimes used to estimate the meibomian gland drop-out rate.

Schirmer's test The test is performed using a 5 x 35 mm whatman 40 filter paper strip the first 5 mm of which is bent and placed in the conjunctival sac without anaesthetic. The rounded tip of the filter paper strips is placed across the lower lid at the juncture of the middle and outer third of the lid margin, avoiding direct contact with cornea (to avoid reflex secretion). The notch of the strip is aligned with the posterior margin of the lower lid at the juncture with the globe. It is necessary to cleanse the lid margin before this test and to avoid handling the strip excessively because oils transferred to the filter paper strip may affect the rate of fluid progression. The patient is asked not to squeeze and to look up as the strips are placed as gently as possible. Patients are then instructed to either close their eyes gently or to continue looking up and blinking naturally. The time between placement of the first and second strips in the other eye is noted to obtain an average time for the two strips. Wetting of the strip is observed and the strips are removed after fully wet or 5 minutes have elapsed. Wetting of the strip is measured in millimetres from the notch of the strip and is calculated in millimetres per minute. Wetting of 1 mm/minute or less is considered abnormal. Normal values are more than 15 mm in 5 minutes. Less than 5 mm is indicative of severe KCS, 5-10 mm as moderate KCS, while readings from 10-15 mm must be interpreted with caution and correlated with other clinical findings. The anaesthetics are avoided as they may alter tear volume and wetting of the Shirmer's strip. A standard method allows the test to be a "stress test" for the lacrimal gland, determining its ability to produce reflex tears.

Modifications of Schirmer's test are the following:

A. Thread test developed by Kurihashi,
B. Kinetic tear flow test, in which the capillary tear flow of Schirmer's strip is prevented from evaporating by a plastic coating of the filter paper.

Rose bengal staining This test is performed last as the dye is somewhat irritating to the eye and produces more reflex tearing than other techniques. Rose bengal stains degenerate epithelial cells and mucous and indicate the state of the tear film base. The impregnated filter paper strips are moistened with tears or saline. After an adequate volume has been delivered to flood the ocular surface, 1 minute is allowed for staining to occur. The ocular surface is then rinsed with non-preserved saline to get rid of mucous strands that

may settle on the ocular surface complicating the recognition of surface stains. The eye is then examined using broad beam with low-illumination. Rose bengal staining can be graded according to the method of van Bijsterveld, who assigned a maximum total score of 9 to the eye, with a maximum score of 3 to each of the nasal conjunctiva, cornea and temporal conjunctiva. A score of 3.5 indicates the lower limit of an abnormal score.

This dye is ideally suited for examination of the conjunctival changes in dry eyes. Corneal changes are better visualised with fluorescein stains with the exception of filaments, which are better stained with rose bengal.

The staining patterns with rose bengal in dry eyes are classified as the following:

Type A—Confluent staining of the wedge-shaped area of the interpalpebral conjunctiva, with staining of the filaments on the cornea, often with staining of the entire corneal epithelium, which is devitalised, seen in severe dry eye.

Type B—Blotchy uptake of rose bengal in the interpalpebral area, usually with patchy staining of the corneal epithelium seen in moderate dry eye.

Type C—Scattered punctate staining of the interpalpebral conjunctiva, with punctate staining of the inferior cornea seen in mild dry eye.

Double staining In this technique the two dyes are used simultaneously in a mixture of equal proportion with physiological saline using 1 per cent concentration of both the dyes.

Fluorescein dilution test (FDT) It uses a fluorophotometer attached to the slit lamp to determine the rate of dilution of 5 per cent fluorescein, 1.5 μl of which is placed on temporal bulbar conjunctiva. Only the central 1 mm of the cornea is subjected to this test. This test evaluates the tear film turnover rate and the tear flow (clearance) rate.

Tear Function index (TFI)

This test is used for quantification of tear function and measurement of two parameters, i.e. value of Schirmer's test with anaesthesia and tear clearance rate. Both parameters are measured at the same time after instilling a mixture of 0.5 per cent fluorescein and 0.4 per cent oxybuprocaine hydrochloride into the conjunctival sac and then performing the Schirmer's test. The tear strip is then evaluated for both the length of wetting and intensity of the staining with the dye (comparing with standard strip colours). The quotient of the two values is claimed to be more sensitive (78.9%) and specific (91%) in the diagnosis of dry eye than each parameter used alone. TFI value of less than 96 is seen in dry eye and less than 34 in patients with Sjogren's syndrome.

Laboratory Test

A. Tear lysozyme assay: Lysozyme is present in the epithelium of the main and accessory lacrimal glands. It constitutes about 30 per cent of the tear protein content. Hence, lysozyme assay is an indicator of the amount of tear production by the main and accessory lacrimal glands.

Methods of tear lysozyme assay

1. Wetted pieces of Schirmer's strips on the plates or Micrococcus tysodeiktius and the zone of lysis measured.
2. By spectrometric analysis of the rate of lysis of bacteria when a wetted Schirmer's strip is placed in suspension of the bacteria. This method is more accurate in measurement.

B. Tear osmolarity determination: This method comprises of collection of 20 μL of tears from the inferior meniscus while avoiding reflex stimulation and evaporation. In eyes with reduced tear production, evaporation leads to increased osmolarity. The normal tear osmolarity is 302 ± 6.30 osm/L. This method is not used clinically though it is a very specific test for keratoconjunctivitis sicca (KCS).

C. Lactoferrin assay: It comprised of 25 per cent of tear protein and is an indicator of major lacrimal gland function. Lactoferrin concentrations are more decreased in patients with KCS associated with Sjogren's syndrome

than in patients with dry eye in the absence of systemic manifestations.

D. Conjunctival impression cytology: With the help of this test abnormalities of surface epithelium and goblet cells are studied. Goblet cell densities are reduced in various ocular diseases, e.g. in KCS it may be reduced by 17 per cent, in ocular pemphigoid and Stevens-Johnson syndrome by 95 per cent and may be completely absent even in early vitamin A deficiency.
E. Conjunctival Scrapings and biopsy: Special immunofluorescent techniques can be used to identify localised deposits of immunoglobulin and complement in epithelial basement membrane disorders like ocular cicatricial pemphigoid. If used in conjunction with labial salivary gland biopsy they may be helpful in establishing the diagnosis of Sjogren's syndrome.
F. Leucocyte esterase: This test is reported to be highly sensitive and specific for detection of associated ocular infection in dry eye.

Methods of tear collection

An ideal method of tear collection would following:

1. allow rapid collection without any ocular irritation,
2. allow efficient and reproducible recovery of both low and high-abundance tear proteins,
3. lend itself to sensitive protein assays such as radioimmunoassay or enzyme-linked immunosorbent assay (ELISA), and
4. be readily applicable in a clinical setting.

The methods currently available are the following:

i. Schirmer's paper test strips
ii. Cellulose sponges
iii. Glass-capillary micropipettes
iv. Porous polyester rods.

Schirmer's paper strips and cellulose sponges are limited by unavoidable stimulation of reflex tearing, thus eliminating the possibility of analysing nonreflex basal tears. Moreover, Schirmer's paper test strips find protein, limiting accurate recovery and quantitation. Glass-capillary micropipettes have limitations because they often collect tears slowly and unpredictably and are cumbersome to use in a clinical setting. Porous polyester rods are also tried recently for tear collection Tears are collected by these two methods from the inferior lateral tear meniscus under direct slit lamp observation, minimising irritation of the ocular surface or lid margin.

These tests are greatly facilitated by a slit lamp biomicroscope. *Note:* Do not use any topical anaesthetic while testing with dye.

5. Measurement of Corneal Size

This is indicated in an infant with cloudy cornea or inequal size of the cornea. Sedation or general anaesthesia should be employed while measuring the cornea of an infant. In adult, a topical anaesthesia suffices. *A* caliper used in squint surgery is a suitable instrument. Measure the white to white diameter of the cornea. In case of large cornea in an infant, the anteroposterior length of the eye should be measured by *A* - scan ultrasonography.

6. Slit Lamp Examination

Discussed later (p. 65).

7. Keratoscopy and Keratometry

Discussed later (p. 72).

8. Special Examinations of Cornea

Pachymetry and specular microscopy are two special examinations of the cornea, not routinely performed but are important in clinical research and some surgical procedures.

PACHOMETRY (PACHYMETRY)

Corneal thickness is measured by pachometry (pachymetry). This measurement is an important indicator of corneal endothelial function and is also necessary for radial keratotomy incision planning.

It is currently done by the following methods:

1. A special attachment to the slit lamp gives a split image of the corneal section. When the amount of doubling is adjusted in such a manner that the anterior surface in one image lines up with the posterior surface of the other,

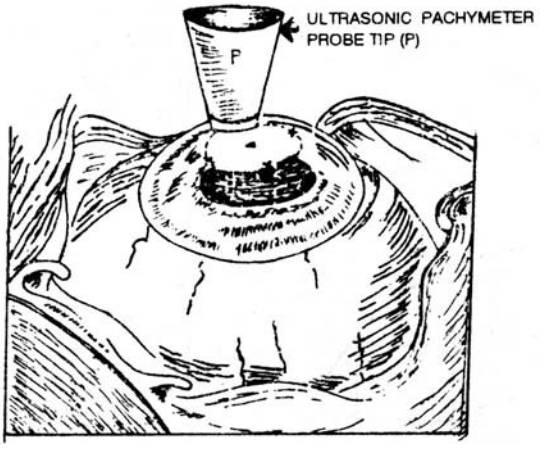


Fig. 4.13: Paracentral corneal thickness is determined by placing the probe tip just outside the clear zone mark (dotted line) made by the dull marking trephine

the corneal thickness can be measured directly from a dial. The measurement of the thickness must be done perpendicular to the cornea.

2. Certain specular microscopes are calibrated in such a way when the endothelium is focussed, the corneal thickness is automatically displayed digitally.
3. *Ultrasonic Pachometry:* The ultrasonic pachometer averages multiple readings taken in one to two seconds by the sound waves of a probe, when it is held within ten degrees of the perpendicular to the corneal surface (Fig. 4.13). Gel or solid tips are now replacing the original water filled probes.

Method

A. *Probe test* The condition of the probe can be confirmed by using the probe test mode. Water is wiped off the tip of probe by absorbent cotton and the condition of no touching is made at the tip of the probe. The result is checked.

B. *Measuring corneal thickness* The measuring map is selected by the numeric keys. The probe tip is touched vertically on to the patient's cornea and corneal thickness measurement is started. When the corneal sound is measured, short peep sounds are heard and the measured value is displayed. In order to obtain the more accurate value, the corneal thickness is measured at one point several times. If the measurement could not be made, an electronic sound which is different from the above sound is heard and the error message is displayed. The next measuring point is selected. The tip of the probe is touched vertically on to the next measuring point of the patient's cornea and the thickness is measured. By repeating the procedure, all desired points are measured. The points we measure are in four concentric rings—paracentral, mid-periphery, para-periphery and periphery. The converted velocity used in the corneal thickness measurement is 1640 m/s (Fig. 4.14).

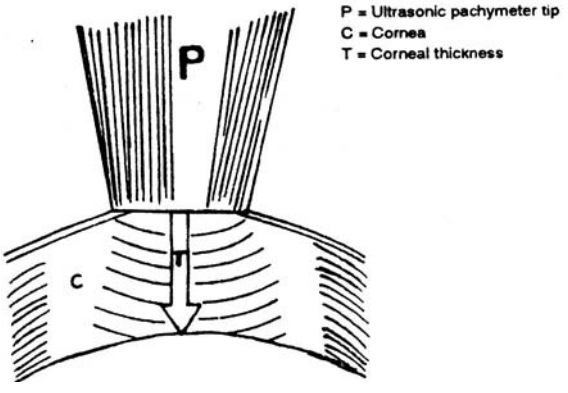


Fig. 4.14: The ultrasonic pachymeter probe tip is touched on the surfaces of the cornea. Ultrasonic waves are emitted and detected by the probe. The computation of corneal thickness is based on the speed with which sound travels through the cornea

C. *Confirmation of measured corneal thickness values:* The measured values for one point are considered and the average values and standard deviation for each point are calculated. Thus the measured values can be confirmed easily.

Measuring corneal thickness is often an useful parameter when subclinical oedema is suspected in the presence of guttate or after disease or surgery. The normal central corneal thickness is about 0.52 mm and higher values indicate some

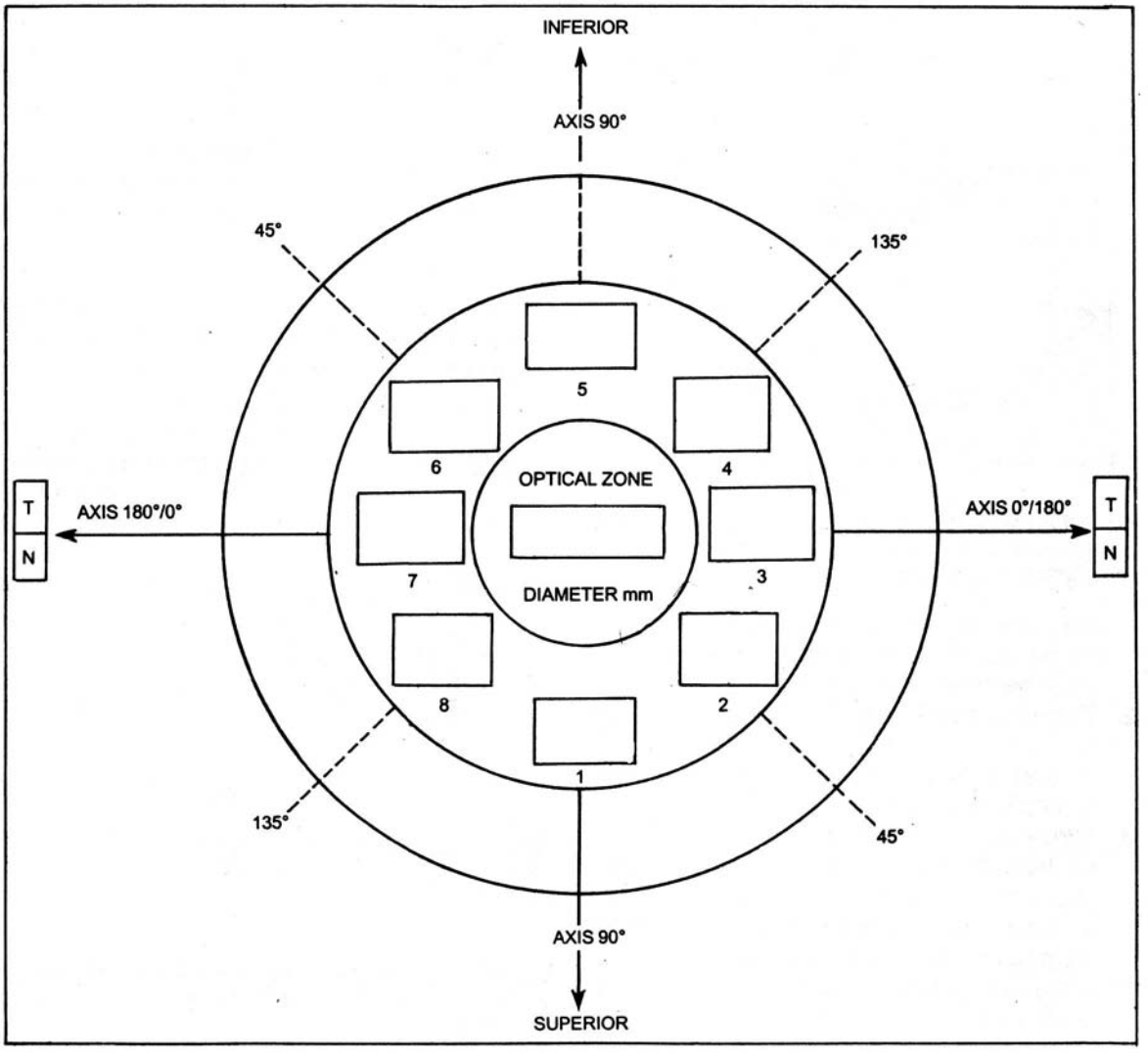


Fig. 4.15: Pachymetry template

endothelial dysfunction. Epithelial oedema with consequent diminished vision usually does not occur until the corneal thickness is 0.65 to 0.75 mm provided the IOP is normal. But if the pressure is elevated, epithelial oedema occurs at a lesser thickness. The pachometric values also help us to estimate the functional reserve of endothelium in a clear cornea. A reading of about 0.50 mm is reassuring for the future whereas if it is around 0.70 mm it indicates border line decompensation and risk of imminent epithelial oedema (Fig. 4.15).

SPECULAR MICROSCOPY

Corneal specular microscope is a reflected-light microscope which projects light onto the cornea and images the light reflected from an optical interface of the corneal tissue. The projected light

can be in the form of a stationary slit, a moving slit, or a moving spot. The optical design can either be confocal or non-confocal. Although this instrument is usually used to evaluate the corneal endothelium, the corneal epithelium and stroma and even the crystalline lens can also be visualised and evaluated.

For the normal transparent cornea, most visible light that falls on the epithelial surface is transmitted. As the light passes through the corneal tissue, some of it can be absorbed by the tissue and some can be reflected by nerve fibres, keratocytes and other refractile objects. In the stroma most of the light is transmitted, although a small amount is absorbed and/or scattered by cellular organelles. With increased corneal oedema, the amount of scattered light increases thus giving rise to a "hazy" cornea. As light strikes the posterior corneal surface, almost all of it is transmitted into the aqueous humor. As there is a change of refractive index at the endothelium-aqueous humor interface, about 0.022 per cent of the total incident light is reflected; this reflected light is captured by the clinical specular microscope and forms the endothelial image.

If the angle of incidence of the illuminating source is increased a wider slit can be used and a larger field of endothelial cells can be seen but it will also illuminate more of the corneal tissue anterior to the endothelium, so that the volume of "interfering stroma" increases and more light is scattered back to the image plane of the specular microscope resulting in a decrease of contrast of the endothelial image and a loss of cellular definition.

The endothelial cells are transparent and thus are difficult to visualise using direct illumination. The difference in refractive indices between the endothelial cell and the aqueous humor gives rise to a specular or mirror-like reflection, at the flat posterior surface. The endothelial cells can be seen in a mosaic pattern where the cell boundaries are seen as dark lines. Any irregularity in the smooth surface, e.g. the intercellular borders, guttatae or swollen endothelial cells, scattered light, appears as dark areas in the mosaic. Reflected light from the epithelium and stroma obscures the view of the endothelium unless a narrow slit beam is used for illumination. Of primary importance in clinical specular microscopy is the light that is reflected specularly (i.e. mirror-like), where the angle of reflection is equal to the angle of incidence.

Clinical specular microscopy yields an image with three to four distinct zones, depending on the width of the illuminating slit.

Zone I—Epithelium/lens-coupling fluid

Zone II—Stroma

Zone III—Endothelium

Demarcation line between zones II and III is called the bright boundary

Zone IV—Aqueous humour.

The demarcation line between zones III and IV that separates the illuminated cornea from the non-illuminated structures located more posteriorly is called the dark boundary.

Specular microscopes are of two types—contact and noncontact.

Contact specular microscopes Here the dippling cone objective applanates the cornea and eliminates the epithelial light reflection. These offer good resolution and high magnification, though the patients are less comfortable and there is risk of spread of infections. There is also chance of artifacts particularly in fragile, diseased cornea.

Non-contact specular microscope It relies on the observer to find out the zone of specular reflection. The main advantage is greater patient tolerance and acceptability. A broader view is obtained, at the expense of resolution and magnification due to uncontrolled eye movements. There is no risk of corneal trauma.

Wide field specular microscopes combine the advantages of both these microscopes. The field of view is 10-15 times larger, the resolution is high and image quality is less susceptible to eye movements. Endothelial layer topography is more readily studied, the relocation of a specified region of the endothelium is easy, and the larger field offers more accurate cell counts.

Methods of Analysis

Qualitative morphometric analysis Qualitative cellular analysis identified abnormal endothelial

structures and grades the endothelium either according to the number of size of the abnormal structures present or on the basis of an overall visual assessment of endothelial appearance. Complete qualitative analysis requires that several parameters, e.g. cell conformation, cell boundaries and their intersections, configuration of the dark boundary and the presence of a cellular structures, should be evaluated

Quantitative morphometric analysis Various morphologic parameters can be qualified, including cell size (cell area or cell density), polymegathism (variation of cell size such as coefficient of variation of mean cell area), pleomorphism (variation of cell shape such as per cent of hexagonal cells or coefficient of variation of cell shape) cell perimeter, average cell side length, cell shape, and so forth. Histograms or frequency distributions of these quantities can also be determined. To date only pleomorphism, polymegathism, and several variables related to these parameters have proven useful in determing endothelial status. Two parameters have been used to quantify endothelial cell size. They are mean cell area and cell density (or cell count). Cell area has been most often expressed in units of square micrometers (μm^2) per cell and cell density in units of cells per squate millimetre (mm^2).

a. *Cell count* The number of cells in a photographic field of known area.
b. *Fixed frame analysis* Comparison of the cells with drawings of endothelial mosaic of known size.
c. Tracings of individual cell outlines and subsequent analysis for individual cell areas and other parameters.
d. Cells may be digitised after tracing their outlines.
e. Computerised image analysis.

In using this instrument the patient is instructed to place his or her chin onto either the left or right chin rest, depending on whether the photographs of the left or the right eye is desired, and to look at the green fixation light. The operator needs only to adjust the chinrest vertically and move the head slightly to the right or the left until the pupil of the eye, seen on the video-monitor on the front of the instrument, is approximately centred. The operator then presses a red button on the control box to start the automated photography process. The optics of the instrument first objectively aligns itself relative to the cornea by using the Purkinje images until the proper specular reflection mode is achieved. The instrument then objectively focusses back to the endothelial surface, the green fixation light begins to flash on and off (indicating that the patient should not blink), the flash lamp is triggered, and the resulting endothelial photograph is displayed on the video-monitor. This instrument does not require a trained operator. Even the patients can take their own endothelial photographs by looking into the instrument and pressing the red buttom to start the automated photography process.

Measuring the parameters of cell size are usually performed by two methods—fixed frame analysis and variable frame analysis. In fixed frame analysis one counts the number of cells within a frame or window of constant area. All cells lying completely within the frame are counted as whole cells. Each cell that is only partially within the frame is counted as half cells. In variable frame analysis, one measures the variable area occupied by an integral number of cells. The variable frame area is obtained by using either a planimeter or a digitiser.

A minimum of 75 cells should be counted for cell analysis. The early processing methods were time-consuming. Wide field specular microscopy increases the number of cells that could be photographed by providing a 10-15 times larger field. Computerised cell analysis system determines cell boundaries directly from original photomicrographs/video-recordings and provides the mean cell density (cell count), i.e. cells/mm^2 and frequency distribution of the individual cell sizes and analyses the polygonality.

The newer specular microscopes, e.g. konan non-con Robo-ca sp 8000, include an autofocus device to record the specular images readily. With this microscope only the central and four fixed peripheral areas of cornea can be examined.

There is also an incorporated semi-automated image analysing programme. It has a built-in software programme that has two analysing modalities. To calculate the cell density, a rectangular area can be determined manually. All the cells, completely within the border of the rectangle as well as those touching two adjacent borders, are marked. This technique gives only the cell density in cells/mm^2. The other technique is to mark the centre of adjacent cells. This allows automated computation of the mean cell area (ave), maximum cell area (max), minimum cell area (min), number of cells actually analysed (num), mean cell density (CD), standard deviation of the mean cell area (SD), coefficient of variance (CV) and percentage of hexagonality (6A). The reproducibility of the analysis obtained with the konan non-con Robo-ca sp 8000 is high as the autofocus system consistently focusses on the same area of the corneal endothelium.

Morphological changes such as variations in cell size (i.e. polymegathism), cell shape (i.e. pleomorphism) and asymmetry of the cell population may be the more reliable indices of endothelial stress than mean cell density. The degree of uniformity of cell size is determined by measuring the areas of a population of cells and calculating the coefficient of variance (CV) which is the standard deviation of mean cell area divided by the mean cell area (i.e. SD/Ave). The normal CV value is 0.25. An increase means that the cell size is variable which is known as "polymegathism". Cell size varies over a wide range in a number of disorders, and endothelial cells may assume shapes which are much different from the usual hexagonal one. Cell boundaries normally intersect in such a manner that results in three equal angles of intersection. The endothelial mosaic in healthy young corneas consists of 70-80 per cent hexagonal cells. A decrease in hexagonality with a concomitant increase in the number of cells with more or fewer than six sides is known as "pleomorphism". With Konan non-con Robo-ca sp 8000 it is possible:

i. to calculate the individual cell area, with which the coefficient of variance can be deduced as a degree of polymegathism.
ii. to analyse the polygonality, i.e. percentage of hexagonality clinical uses:
    A. Assessment of endothelial changes
        - with ageing
        - with surgeries—keratoplasty, cataract surgery (with or without IOL), PRK, LASIK, etc.
        - with associated glaucoma, uveitis, contact lens wear, trauma
        - with use of intracameral drugs, irrigating solutions and topical medications.
    B. Assessment of endothelium in donor corneas and the effect of preservation.
    C. Assessment of diseases/degenerations/dystrophies.
    D. Assessment of longitudinal effect of surgeries.
    E. Measurement of corneal thickness (pachymetry)—with contact type only.
    F. Assessment of the epithelium of cornea and crystalline lens.

When the corneal thickness exceeds 0.6 mm the endothelial view degrades, preventing pachometry or effective photography of the endothelial layer. Stromal haze also hamper endothelial visualisation.

Endothelial cell density At birth, cell densities range from 3500 to 4000 cells/sqmm, while the adult cornea usually has cell densities of 1400 to 2500 cells/sqmm. Corneal transplants may have less than 1000 cells/sqmm and remain clear. It seems that as long as endothelial cells can enlarge to provide a confluent monolayer on Descemet's membrane, normal corneal function is maintained. A lower limit of this ability occurs at densities of 400 to 700 cells/sqmm (critical) density of endothelial cells) below which endothelial function falters and corneal oedema and loss of visual function occur. A reduction in endothelial cell density alone is not sufficient to cause stromal oedema but when the barrier property of the endothelium is compromised, as occurs in corneal guttatae, the corneal dehydrating mechanism is overwhelmed by ion and water leakage into the stroma through damaged paracellular pathways.

Epithelial specular microscopy Specular microscopic photographs of the corneal epithelium were first obtained by McFarland by using a special plastic conical element that fits over the normal dipping cone objective lens. Using this conical element, saline, hydroxy methyl cellulose, or other fluids could be hold between the glass surface of the contact lens and the epithelium so as to obtain epithelial images. The refractive index matching that occurred because of the fluid interface can be accomplished using the fluorite tip on the objective lens (designed by Sherrard), thus enabling epithelial photography.

Normal corneal epithelium contains polygonal cells with specular reflected intensities (brightness) ranging from dark to light. There are mainly hexagonal, pentagonal and triangular cells but no rounded or elongated ones. Usually most cells are in one of the three groups—dark, medium, and light. The dark cells appear almost black, whereas the light ones are light grey. Cells of similar intensity tend to be grouped together, and the brightness within any one cell is homogeneous. Only the superficial layer of the epithelium can be observed. Elongation of corneal cells is typically seen in wound healing processes, e.g. after PK, PRK, epikeratophakia, and traumatic defect. The elongation of the spindle-shaped cells gradually reduces with healing. Cell elongation is always seen in the first week after PRK but resolves within one month due to accelerated migration of the peripheral cells followed by the re-establishment of the epithelium. In keratoconus, spindle-shaped cells are prominent surrounding the cone's apex. Persistent elongated cells are seen in extended wear contact lens wearers, aphakic patients, diabetic patients after epikeratophakia and in patients with persistent epithelial defects.

CONFOCAL MICROSCOPY

Confocal microscopy is a new imaging technique which provides the ability to section, optically, living or *in vitro* tissues non-invasively over time. Images are obtained from different depths within the thick specimen, thereby, eliminating the necessity for processing and sectioning procedures.

Minsky microscope (1955) condenser focussed the light source within a small area of tissues, with concomitant focusing of the microscope objective lens on the same area. As both condenser and objective lenses had the same focal point, the microscope was called confocal. In modern confocal microscopes, a point light source is focussed onto a small volume within the specimen, and a confocal point detector is used to collect the resulting signal. This results in a reduction of the amount of out-of-focus signal from above and below the focal plane, which contribute to the detected image and produces a marked increase in both lateral (X, Y) and axial (Z) resolution. The use of a point source/detector in the confocal optical design trades field of view for enhancement resolution; therefore, a full field of view must be regained by scanning. Scanning may be achieved either by moving the specimen past a fixed point of illumination by synchronous movement of the point illuminator and detector.

Petran used a single white light source and a modified Nipkow disc containing thousands of optically conjugated pin holes arranged in Archimedean spirals. Rotation of the disc result in even scanning of the tissue by the source pinholes, whereas detector pinholes prevent light from outside the optical volume, determined by the objective lens and pinhole diameter, from reaching a photodetector. Because illumination and detection of light through conjugate pinholes occurs in tandem, this microscope was named tandem scanning confocal microscope. The design of this microscope has several features—(a) it uses subtoxic levels of the white light, which do not produce patient or animal discomfort, (b) it produces realtime images that can be detected by a low-light video-camera and viewed on a monitor, and (c) its optical sectioning ability can provide images from different depths within a thick tissue specimen. Thus, the TSCM allows dynamic viewing of optical sections from the eye in four dimensions (X, Y, Z, and time).

Since the living eye is moving *in situ*, a surface contact lens tip is needed to keep the objective perpendicular to the corneal surface at all times. This has been achieved through the development

of the dipping cone lens which consists of a long working-distance objective with a cone-shaped tip having either a flat or slightly concave front surface and a posterior-convex surface, that is concentric with the axial focal point. With a diameter of about 5 mm and a radius of curvature comparable to that of cornea, such lenses maintain a comfortable optical contact with the eye over extended periods of observation.

In the microscope developed by Tandem Scanning Corporation (Fig. 4.16), the glass disc contains 64,000, 2 μm-diameter pinholes and has a total optical transmittance of 0.25 per cent; the disc rotation speed is 450 rotations/minute. The light path is composed of prisms and mirrors with a stable and easily maintained alignment. The light source is a 100 W mercury lamp, a 24x, 1.5 mm working-distance, 0.6 numerical aperture objective lens is used. The microscope objective has a motorised drive which allows the Z-axis position of the focal plane to be moved in calibrated increments. The section depth (Z-position) can be encoded onto the audio channel of the video system and optionally displayed on each image frame to assist in quantitative three-dimensional

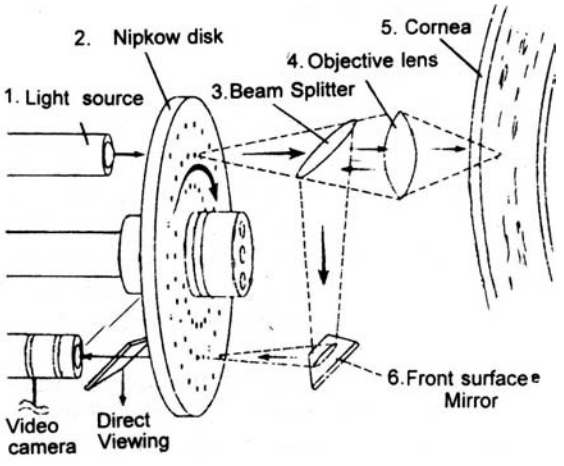


Fig. 4.16: A tandem scanning confocal microscope: A disc with pinholes arranged with conjugate symmetry is used to provide confocal point sources and point detectors. The image can be seen directly or imaged using a low-light level video camera and recorded on videotape and/or continuously displayed on a monitor

analysis. The system field of view with the current objective is 400 x 400 μm with an axial (Z) resolution of 9 μm as determined from the experimentally measured axial response curve. The axial response of the system was determined by focussing through a perfect planer reflector (mirror) and measuring the reflected intensity curve. Either direct observation or video imaging can be used. Images are recorded on a videotape and digitised into a digital disk. Images are then transferred to a computer workstation and further processed using an advanced software programme for rapid two and three-dimensional image analysis and reconstruction. Final images are then photographed with a film recorder.

Before observation, a drop of topical anaesthetic is placed on the patient's eye, and a drop of goniosol is applied to the tip of the objective lens to serve as an immersion fluid. The cornea is then applanated in a manner identical to that used in specular microscopy. The lens does not touch the optical surface, but rides on the thin liquid cushion, thus eliminating the bright surface reflections observed with an air~cornea interface. The X, Y positions of the image is controlled by moving the joystick on the microscope stand and the Z-position is changed using the objective drive control. Typical observation time in a clinical setting is 5 to 10 minutes.

Nowadays most confocal system use a focussed laser beam as the point source and are thus called laser confocal microscopes (LCM). In scanned beam LCM, rotating or vibrating mirrors are used to scan a stationary specimen.

The viewer sees thin slices of the cornea that are parallel to the epithelial surface. The borders of the surface epithelial cells are readily seen, as are the bright nuclei. Immediately beneath the basal epithelium, a fine nerve plexus can be detected. In the corneal stroma, only cell nuclei are visible using TSCM under normal conditions, with a dark background in between. Interestingly, the interconnected cell processes of the keratocytes, become visible under certain pathologic conditions, possibly because of tissue oedema or cell activation. Large numbers of keratocytes

are present in the anterior stroma, as compared to mid and deeper stroma, which show a lower cell density. Prominent nerve fibres can be seen within the stroma and tracked three-dimentionally over long distances. TSCM images of the normal endothelium appear similar to those observed using specular microscopes.

Clinical applications

1. *Acanthamoeba Keratitis*—for localisation of *acanthamoeba cysts* and trophozoites in the living eye.
2. Excimer laser PRK—to study corneal wound healing.
3. *Herpetic keratitis*—enlarged epithelial cells are consistently seen over areas with previous herpetic involvement. Dense fibrosis was observed in anterior stroma. Subepithelial nerve plexi were not observed in the region of scar. Deeper stromal scanning and micro-vascularisation with small capillary twigs were seen near the corneal periphery.
4. Tear film—to measure the thickness of precorneal tear film.
5. Surface toxicity and incisional wound healing—to monitor adverse effects of contact lenses or toxic drug effects on the ocular surface in patients. Likewise recovery and effects of drugs (e.g. tear replacement drops) could be directly assessed. It could also be used to monitor the cellular events of stromal wound healing and assess the efficacy of treatment.

HIGH RESOLUTION ULTRASOUND (ULTRASOUND BIOMICROSCOPY)

Ultrasound biomicroscopy (UBM) uses ultrasound in the frequency range of 40 to 100 MHz to produce cross-sectional subsurface images of the eye at an axial and lateral resolution of up to 20 μm, with penetration limited to approximately 5 mm. Ultrasound in the higher frequency ranges (60 to 80 MHz) can be used for corneal examination because of a lesser need of deep penetration and a greater need for high resolution. Because sound is used instead of light, UBM provides a different type of information on internal structure and allows penetration of optical opacities.

Signal processing in an UBM is identical to that in a conventional B-mode imaging system except that the operating frequency is approximately one order of magnitude higher. A 40 to 100 MHz transducer is moved linearly over the imaging field (typically 4 to 8 mm), collecting radio frequency ultrasound data at each of 512 equally spaced lines (8 μm between lines for a 4 mm field of view). At each location, a 40 to 100 MHz ultrasound pulse is transmitted into the tissue, and the back-scattered ultrasound is detected by the same transducer. The radio frequency signal is received and amplified in proportion to the depth from which it originated using time-gain compensation (TGC). After the radio frequency signal is processed nonlinearly to enhance the low level signals, its envelope is "detected" to produce the A-scan signal. This signal is then converted from analog to digital format and transferred to a special high speed scan converter, stored and displayed as B-scan data on a video-monitor. The servomotion system and signal processing are controlled and synchronised by a computer. B-mode imaging is currently performed at 5 to 10 frames/second.

Examination techniques

UBM is performed using an eye cup and a fluid couplant such as methyl cellulose. The viscosity of methyl cellulose decreases fluid loss during examination. The moving transducer is inserted in the fluid couplant and scanning starts. The scanning head is suspended from an articulated arm, which supports its weight, and fine movements are performed by hand while watching the image on the screen. To stabilise the eye being examined, it is better for the patient to fixate on a target with the opposite eye. The examination is performed with an unshielded moving transducer in close proximity to the eye. A membrane over the transducer would produce unacceptable sound attenuation at this frequency. Care must be taken to avoid contact. The best image of

ocular structure is achieved when ultrasound beam is perpendicular to the structures being examined. Any obliquity will result in part of the back-scattered signal not being detected and will produce deterioration of the image. Small movements of the probe are performed to maximise the brightness of echoes from intraocular structure. When the epithelial and endothelial reflections are maximised, one can be assured that reasonable perpendicularity to the cornea has been achieved.

Three prominent specular echoes received from the following:

1. The fluid couplant—epithelial interface
2. The epithelium—Bowman's membrane interface
3. The endothelium/Descemet's membrane—aqueous interface (The Descemet's membrane and endothelium cannot usually be differentiated from each other). The distance between 1 and 2 represents epithelial thickness and the distance between 2 and 3 represents stromal thickness.

UBM of oedematous cornea shows increased corneal thickness and higher reflectivity of the corneal stroma. The epithelium is usually thickened and the smooth highly reflective surface line replaced by a more irregular less reflective line. Epithelial bullae can be discerned as a slight separation of the corneal epithelium from the underlying Bowman's membrane.

USE OF MAGNIFIERS IN OPHTHALMOLOGY

This portion is added in this book because these surgical aids are also useful for examination, especially in children under general anaesthesia or sedation. These magnifiers help to detect minor abnormalities and intricate structures in greater detail.

Commonly used magnifiers are the following:

1. Magnifier on head band
2. Operating spectacle
3. Operating microscope

Magnifier on Head Band

Among the magnifiers available, it is the cheapest and easiest to use. The magnification is low and can be routinely used for preliminary examination of the anterior segment and external eye. For example,

a. Lid margin, lashes, punctum
b. Conjunctival and corneal injuries and foreign body
c. Pupil and iris.

How to use the instrument Put on the magnifier on your head with the help of the band. Swing the loupe in front of your eye. Put your palm in front, adjust the angle of the magnifier and the distance of the palm till you see the palmar creases clearly. With the idea of the distance go on to examine the eye. Illuminate the area of interest with a pen torch while examining (Fig. 4.17, Plate 6).

Operating Spectacle

These magnifiers are essentially Gallilean telescope mounted on spectacle frame. To the frame, correcting glasses for distance vision is to be incorporated for emmetropia. Operating spectacles with different magnifications are available ranging from 2.5x to 10x and even more. For all practical purpose of examination and anterior segment surgery 4x magnification serves well (Fig. 4.18, Plate 6).

How to use the instrument Adjust the interpupillary distance of the spectacle to your own. Wear it as a spectacle. Do not wear the spectacle very close to the eye. This will prevent fogging of the lens. Keep the axis of the spectacle as close as possible to the axis of the eye being examined. A pen torch which can be focussed to a point is necessary to illuminate the point of interest.

Care of operating spectacles After use, clean the body of the spectacle with soft tissue paper or cloth soaked in clean water. Blow air puff over the lenses to remove loose dust. Soft brush may also be used. Then wipe lightly with clean moistened tissue followed by a piece of dry tissue.

Keep the operating spectacles in its container properly closed. Put few packs of desiccating substance like aluminium silicate in the container to prevent moisture accumulating on the lenses.

Do not open the lenses. The alignment of the instrument may be lost.

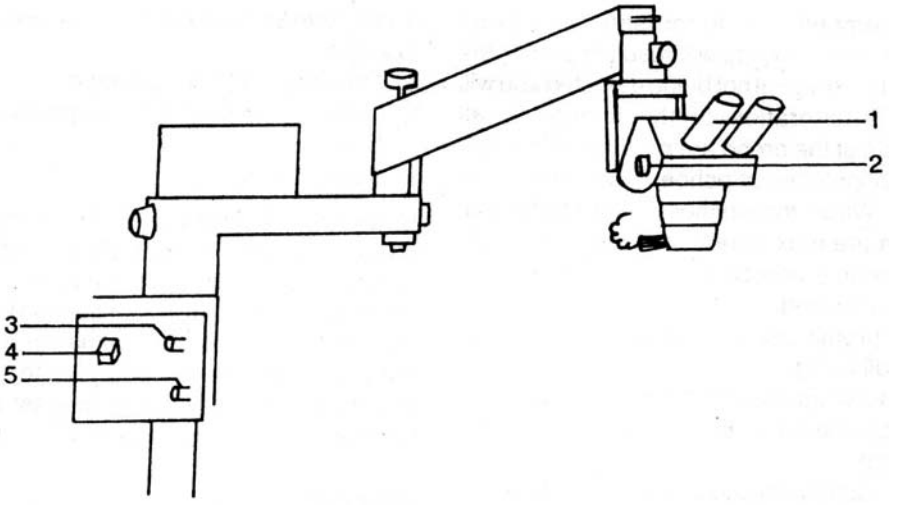


Fig. 4.20: Operating microscope. 1. eye piece, 2. focussing, 3. fine focus speed (controlled by foot switch), 4. switch to main with indicator lamp, 5. illumination intensity control

Operating Microscope

Today's sophisticated eye surgery ensures better visual result which could not be achieved without operating microscope. The basic advantages of operating microscope over operating spectacles are the following:

i. The magnification can be changed as required.
ii. Coaxial and oblique illumination—both can be used as necessary.

Part of the instrument (Fig. 4.19, Plate 6) The instrument essentially consists of two parts:

i. A pair of magnifiers for binocular vision; the magnification and the interpupillary distance can be changed as necessary.
ii. A system of cold illumination which is almost coaxial with the occulars.

These parts are held together in the body of the microscope which is usually attached on a mobile stand or alternately it can be mounted on the ceiling (Fig. 4.20).

A microscope with manually operated focussing and magnification serves well for most anterior segment surgery. For posterior segment surgery, a motorised foot control for focussing and magnification are essential. In some sophisticated (and expensive) microscopes, foot control for X-Y movement is also available (Fig. 4.21).

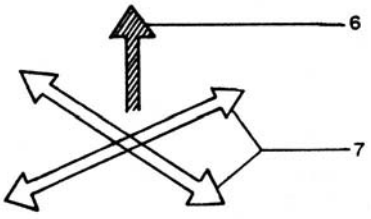


Fig. 4.21: Movements of microscope. 1. vertical movement, 2. X-Y movement. Controlled by foot switch

Before use, get yourself acquainted with the following parts of the operating microscope:

a. Cord to main
b. Microscope switches for fan, light and intensity control
c. The microscope arm, levers and knobs/screws to fix the arm
d. The eyepiece and mechanism for adjusting the pupillary distance
e. Knobs/screws for adjusting the inclination of optical head, focussing and magnification
f. Motorised foot switch (if available) for focussing, magnification and X-Y movement
g. Lamp house and the cord to optical head.

STEPS FOR PREPARATION OF
THE MICROSCOPE READY FOR USE

i. Plug in the cord to the mains.
ii. Switch on the microscope. This will switch on the cooling fan in the microscope.
iii. Switch on the light, increase the intensity slowly to the required level.
iv. Loosen all the locks and move the eyepiece to the operation table.
v. Adjust the focussing and finally lock the microscope arm as necessary.

Adjustment of Focussing

1. Adjust the pupillary distance. If the PD scale is attached to the microscope, adjust to your distant PD. Alternately, keep the eyepieces wide apart and try to look through them while closing them slowly. Keep your eyes as close to the eyepieces as possible. Initially, you would find parts of two illuminated circles which will be gradually overlapping as you go on pushing the eyepieces closer. Stop as soon as you find one complete circle. Close one of your eyes and inspect if you can see one complete circle. Without moving your eyes, close the other eye and observe what you see. You should see one complete circle with either eye as well as both the eyes open. Adjust the distance between the eyepieces till the goal is achieved.
2. Put a piece of small graph paper under the objective lens at the approximate height of the patient's eye.
3. Rotate the eyepiece tubes outwards (anticlockwise), to the extreme.
4. Set the highest magnification (zoom), and lower the microscope arm while looking through the eyepieces to focus the graph roughly. Use the fine adjustment to sharply focus the graph.
5. Set the microscope to lowest power setting while you would find the graph to be out of focus.
6. Close one eye. Look through the eyepiece and slowly rotate the eyepiece tube inwards (clockwise). Stop at the point when the graph is sharply focussed. Repeat the same procedure with the other eye.
7. Keep both the eyes open and change the magnification to highest (zoom). Refocus with fine adjustment.
8. Change the magnification to low power and refocus with each eyepiece one by one as in 6.
9. Adjust the intensity of the light and magnification to the minimum required for the procedure.

Some Tips on Use and Care of the Operating Microscope

a. Sit comfortably otherwise you would become tired midway of the procedure.
b. Keep your eyes as close to the eyepiece as possible; this will increase the field of view.
c. Avoid accommodation. Change the magnification as necessary.
d. Clean any dirt, blood stain or fluid from the microscope after surgery with a soft cloth soaked in weak detergent.
e. Regularly clean the body of the microscope and the lamp house. Lubricate the wheels.
f. Cover the microscope properly after use to prevent dust accumulation. Always blow off the dust from the eyepiece before and after use.
g. If you are not using the microscope for a few days, light on the microscope daily for about five minutes. This will warm up the microscope and prevent fungus growing.

SLIT LAMP EXAMINATION

The slit lamp examination is a method by which the eye can be examined under magnification with some added advantages. The slit beam of the instrument can produce an optical section on which the exact location of the pathology can be identified. A stereoscopic image is produced which gives all the advantages of binocular vision. With special attachment, the angle of the anterior chamber, the vitreous and the retina can be examined. Under this heading, the basic uses of the slit lamp will be discussed.

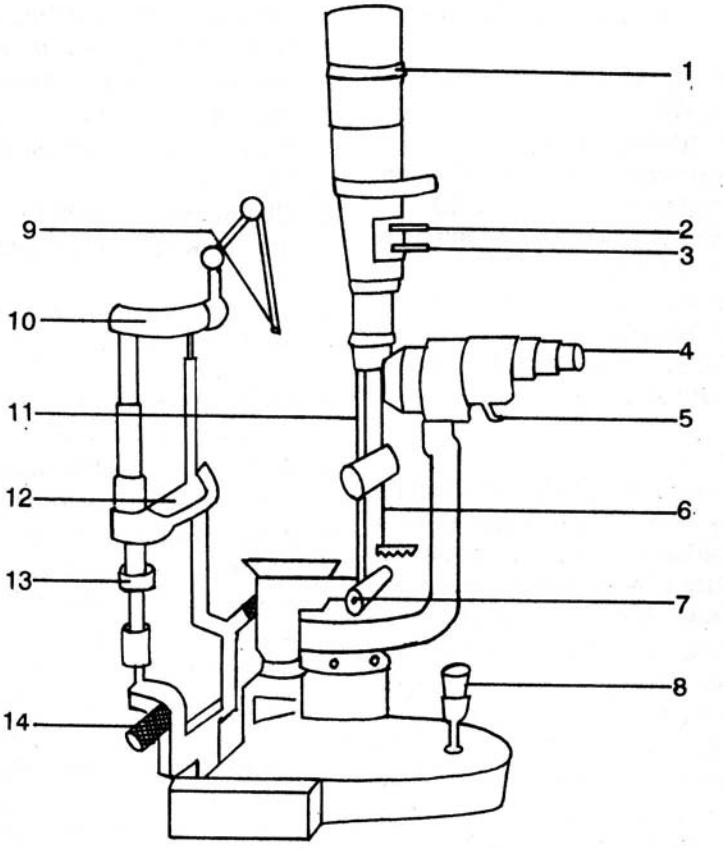


Fig. 4.22: Slit lamp biomicroscope. 1. lamp housing, 2. filter selection lever, 3. aperture selection, 4. eyepiece, 5. objective changes for magnification 6. lever for tilting illumination, 7. slit width control, 8. joy stick control, 9. fixation light, 10. headrest, 11 reflecting mirror, 12. chinrest, 13. height adjustment, 14. handrest

The Instrument

All the models of slit lamp basically consist of a lighting system by which light can be focussed on the point of interest. The light beam can be changed from a point to a circle as well as from a narrow slit to a wide one, the height of which can be adjusted. For observation, a system of binocular magnifiers is incorporated in the instrument. The magnification can be changed within limits (Fig. 4.22).

Parts of the Instrument

As the Haag-Strait model is widely used, this model is described here. The basic structure is almost same in other models.

At the top of the middle structure is the lamp housing, which can be opened to change the lamp. Below the lamp housing there are three knobs. The uppermost is for aperture selection. On moving the knob from one side to other, the aperture is reduced or increased. The middle knob can rotate the slit beam, i.e. it can rotate the beam from vertical to horizontal. Another knob is used to insert redfree and blue filters. At the lowest part of the structure is the roller knob by which the width of the beam can be changed from narrow to wide. Just above the knob is a lever by which the whole structure can be moved on the transverse axis. This movement changes the tilting angle of the structure, i.e. the illumination.

The joy stick on the table can be moved forward-backward and sideways. By this, the microscope is focussed on the point of interest, anterior cornea to anterior vitreous without any special attachment. The middle structure can be moved to focus the light beam on the point to be observed or elsewhere as necessary. At the eyepiece holder, the emmetropia of the examiner can be corrected. Below the eyepiece is the magnification changer, by swinging which you can change the magnification. Exactly at the opposite side of the viewing system is the structure to hold the head of the patient. After sitting on an adjustable stool, the patient puts his chin on the flat chinrest and forehead on the headrest. For better stability two transverse bars are fitted on this structure for resting the hands of the patient. Just below the vertical structure holding the chinrest, on the left is a roller screw by which the chinrest can be elevated or depressed to the desired height so that the level of the eye is at the middle of the total vertical excursion of the magnification system.

The Examination Proper

After the head of the patient and the height of the instrument is adjusted, proper illumination is selected by the switch and regulator below the table.

For rapid scanning of the anterior segment, diffuse illumination is selected by opening all the apertures, thus making the beam a large circle. The beam if thrown from the temporal side becomes easier to scan rapidly.

Now the beam is gradually narrowed and moved to the point of interest. The beam and the microscope both are focussed on the same point thus making the illumination focal. By focal illumination, conjunctiva, anterior surface of the cornea lens, etc. are examined. If the light is moved slightly to one side, it becomes indirect focal. By sclerotic scatter, minute opacities of the cornea can be located. By this method, the beam is focussed on the limbus of one side, temporal or nasal. The light emerges at the other side as in fibre optic. Now the cornea is scanned with the microscope mainly at the centre.

If the light beam is directed to the iris and the cornea is examined against the reflected light, opacities or irregularities will become prominent as dark silhoutte. In the same way, the lens can be examined when the light is directed to the fundus in an eye with dilated pupil (Fig. 4.23, Plate 6).

The clarity of the aqueous in anterior chamber is judged by throwing a very narrow beam from one side. Normally, the beam cannot be seen. If the aqueous is turbid, the path of the light beam can be seen. Cells in the fluid are shown as sparkling spots if the beam is very small.

The slit lamp examination should be undertaken in an orderly manner and all the structures of the anterior segment should be examined. Additional attachment and examination with those, will be described elsewhere (Fig. 4.23, Plate 6).

Slit lamp Examination

Techniques of illumination

Direct		*Indirect*
Any situation where the beam of light is directed to strike the principal subject area.		Uses of secondary surface that reflects light onto the principal subject area or light is transmitted through tissue from an area of adjacent illumination.
Diffuse	Focal	

Direct Illumination

A. *Diffuse illumination*

Broad beam of light is spread by diffusing filter (Fig. 4.24).

Set-up

- 30-45° angle between slit lamp and microsope
- Wide open slit width
- Diffusing filter
- Low to medium magnification
- Medium to high illumination
- Illuminator is rotated through its arc of travel from side to side to create alternatively axial and tangential illumination.

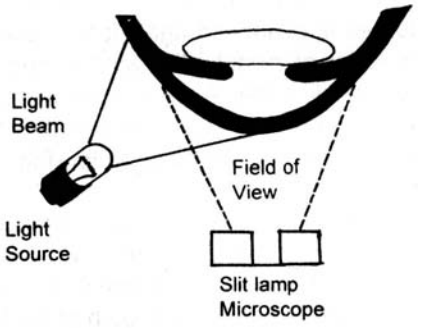


Fig. 4.24: Diffuse illumination

To observe

- General view of the anterior eye and the palpebral conjunctiva.
- Contact lens fitting characteristics, e.g. centration, movement.

Uses

It facilitates simultaneous observation of large areas at low magnification.

Examples of conditions seen in diffuse illumination are the following:

Sclerocornea; Band keratopathy; Trichiasis; Distichiasis; Pinguecula; Papillae; Hordeolum; Entropin, Megalocornea; Lagophthalmos; Poliosis; Pterygium; Follicles; Hypopion; Ectropion; Corneal pannus; Blepharitis; Arcus senilis; Xanthelasma; Chalazion; Hyphema, etc.

B. *Focal illumination*

The slit beam and microscope are focussed in the same area (Fig. 4.25).

Set-up

- 30-45° angle between slit lamp and microscope

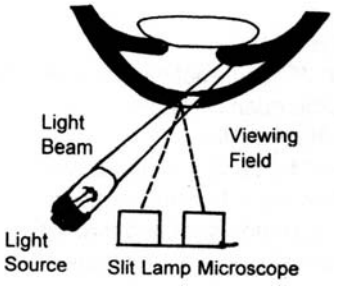


Fig. 4.25: Direct (Focal) illumination

- Medium to high illumination
- Slit beam.
  - i. Optical section: narrow, focussed slit. Observe variation in corneal curvature, corneal thickness and depth of foreign body.
  - ii. Parallelepiped (Broad beam illumination). Wider (3 mm), focussed slit. Observe—Corneal Stroma, epithelial break-down, lens fit, lens surface and endothelium.

Examples of conditions seen in optic section are the following:

Oedema; Stromal opacities; Marginal dystrophy; Kayser-Fleisher ring; Fuch's dystrophy; Corneal pannus; Epithelial defect; Corneal infiltrates; Furrow dystrophy; Lens opacities; Dellen, Microcysts, Bullae, Ectatic changes; Anterior chamber depth; Tear film deficiency; Corneal thinning.

Examples of conditions seen in broad-beam illumination are the following:

Corneal vascularisation; Basement membrane dystrophy; Reis-Buckler's dystrophy; Schnyder's crystalline dystrophy; Terrien's marginal dystrophy; Amiodarone vortex dystrophy; Prominent corneal nerves; Salzman's nodular degeneration; Posterior embryotoxon; Corneal scars; Lisch nodules; Keratic precipitates; Granular dystrophy; Iris atrophy; Pterygium; Band keratopathy; Macular dystrophy; Arcus senilis.

Tyndall's light/anterior chamber cells and flare

Based on Tyndall's phenomenon, pinpoint illumination is maximally effective in isolating aquous cells and flare. A small, round beam of high intensity is directed tangentially through the anterior chamber, and the focal point of the light is swept through the aqueous to find out the presence and density of cells and flare. For maximum contrast, cells and flare should be observed against dark background of a dilated pupil, while minimising the light striking the iris. The standard beam size is 1 x 3 mm. The number of actual cells seen within the beam is counted.

C. *Specular reflection*

View the appearance of a surface, particularly the epithelium and endothelium (Fig. 4.26).

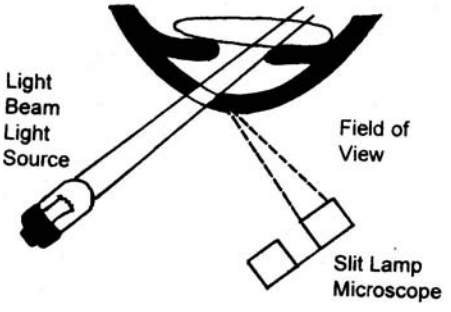


Fig. 4.26: Specular reflection

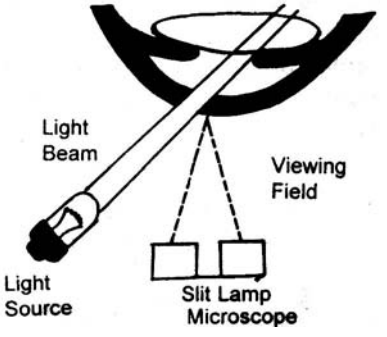


Fig. 4.27: Indirect (proximal) illumination

Set-up
- 60° angle between slit lamp and microscope (larger angle helps to obtain strong reflection)
- Parallelepiped, moderate slit beam
- Move illumination arm until bright reflex is observed
- Angle of incidence = Angle of reflection
- To obtain a clear view of the endothelial cells, a magnification of 25x to 40x is required, though endothelium can be evaluated at a lower magnification too.

To observe
- Individual cells of the endothelium, i.e. polymegethism, guttatae, smoothness
- Tear layer stability and lipid layer

Indirect Illumination

A. *Proximal illumination*

Focus the light beam on a position just beside the area to be examined. The principal subject is thus illuminated by light transmitted through the tissue (Fig. 4.27).

Set-up
- 30° to 45° angle between slit lamp and microscope
- Moderate beam width
- Low, medium or high illumination
- Slit beam can be offset.

To observe
- Corneal microcysts
- Vacuoles
- Epithelial cells.

B. *Sclerotic scatter*

Focussing a narrow beam obliquely at the limbus illuminates the cornea by internal reflection. It permits illumination of the entire cornea against a largely unilluminated background (Fig. 4.28).

Set-up
- Narrow/moderate sized intense beam
- Wide viewing field
- 30° to 45° angle between slit lamp and illuminator
- Low magnification.

To observe
- Any opacity in transparent cornea
- Corneal oedema (area of oedema appears as a grey patch), corneal clouding (oedema caused by a contact lens).

Examples of conditions seen in sclerotic scatter are the following:

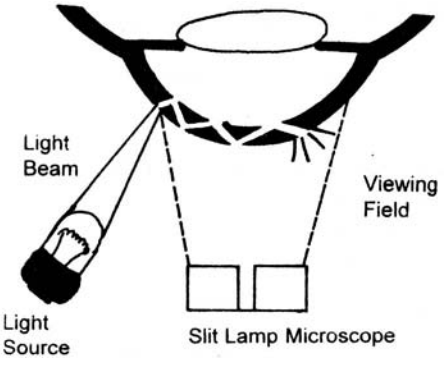


Fig. 4.28: Sclerotic scatter

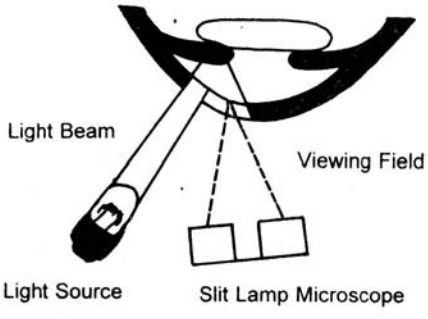


Fig. 4.29: Retro illumination

Corneal foreign bodies; Corneal oedema; Keratic precipitates; Verticillate; Interstitial keratitis; Granular dystrophy; Radial keratotomy scars; Hydrops.

In the normal cornea, this light passes through the stroma undisturbed and is visible only as a ring of light at the limbus.

C. *Retroillumination*

Light is reflected off the iris or fundus, while the microscope is focussed on the cornea (Fig. 4.29).

Set-up

- Vary angle between slit lamp and microscope, offset slit beam
- Parallelepiped
- Direct or indirect observation.

To Observe

- Cornea—neovascularisation, oedema, microcysts, vacuoles, infiltrates.
- Contact lens—front and back surface deposits.

Examples of abnormalities seen in retroillumination from the fundus are: Lattice dystrophy; Pseudoexfoliation; Keratic precipitation; Corneal scars; Meesman's dystrophy; Map, dot, finger print dystrophy; Lens Vacuoles; Cataract; Corneal rejection lines.

Examples of conditions seen in direct and indirect retroillumination from the iris are the follwing:

Lattice dystrophy; Corneal foreign bodies; Meesmann's dystrophy; Finger print, map, dot dystrophy; Cornea farinata; Descemet's folds; Keratic precipitates; Thygeson's superficial punctate keratitis; Corneal infiltrates; Early oedema; Filaments; Microcysts; Fuch's dystrophy; Corneal scars.

Using the light reflected by the retinal pigment epithelium, the anterior vitreous, lens and cornea may be examined by retroillumination. The slit lamp illuminator is placed into an axial position with the biomicroscope and the light is introduced through a dilated pupil to illuminate the fundus with little movement of the illuminator to either side of centre, the optimum position is found where the greatest retroillumination effect is achieved. Leaving the iris unilluminated ensures maximum visitility. Light striking the iris causes scatter.

Sclerotic scatter produces dark field (illuminated against a dark background) whereas retroillumination from the fundus is a bright field (silhouetted against a bright background) technique. Dark field is needed to demonstrate changes that primarily reflect light, and bright field produces best contrast for opaque changes and those that are refractile.

Finger print dystrophy is beautifully displayed in the orange light characteristic of this form of illumination. Cataract formation or lens sublaxation is nicely demonstrated.

For iris transillumination, a pupil size of 2 to 3 mm is ideal.

Other uses of Slit Lamp

Gonioscopy Described in Chapter 6.

Filtered illumination It highlights certain conditions and lens fitting characteristic.

A. *Fluorescein staining*

Set-up

- Cobult blue light
- Wratten filter (# 12, yellow).

To observe

- Corneal staining pattern
- Rigid gas permeable lens fitting.
- Tear film break-up time.

B. *Rose bengal*

Set-up

- Blue filter
- As it causes irritation, topical anaesthetic should be used prior to examination

- Better observed when viewed in a matrix of fluorescein.

To observe

- Staining of both cornea and conjunctiva
- Stains both devitalised and de-epithelised area
- Rose bengal absorbs much of the blue light and its dark appearance contrasts well with a brightly fluorescing back ground.

Seidel test Used to determine corneal or conjunctional patency. Fluorescein dye is applied directly to the suspected site of aqueous leakage. When leakage is present, escaping aqueous dilutes the fluorescein to flow down the surface of the eye, even in the presence of a modest flow.

Pachymetry For the slit lamp two attachments were developed for depth measurements of the eye—a corneal thickness measuring unit and an anterior chamber depth micrometer, also called pachymeters. The only difference between them is the measuring range, which is 1.1 mm in the corneal pachymeter and 6 mm in the anterior chamber pachymeter.

The self-illumination system is used to place an optical section with small slit width and aperture in the direction of the surface normal. For observation the microscope is arranged at an angle of 40°. Observation is done monocularly with a magnification of 12x or 8x. A plane parallel plate which covers half the entrance pupil and is rotatable about a vertical axis is used to produce a double image which is movable. If the section of the anterior corneal surface of the image and the section of the posterior corneal surface of the other image are brought to coincidence by rotating the plate, the lateral beam displacement by the measuring plate gives the corneal thickness which can be read off the scale. The depth of the anterior chamber is read off in the same way.

In addition to the measuring plate there is a second plate which is perpendicular to the microscope axis and fixed in position. This plate covers the other part of the entrance pupil. Its thickness is different from that of the movable plate. The plate thickness is so selected that both the coinciding points are seen sharply defined at the same time.

Furthermore, there is an image dividing eyepiece so that the two pictures are not superimposed but are confined to the upper and lower halves of the field of view. In the area of the sharp dividing line the coincidence can then be set easily and precisely.

Length and angle measurement A device on the slit lamp for length and angle measurment is a great advantage for contact lens fitting.

The length measurement is important, e.g. for measuring the diameter of the cornea, whereas angle measurement is useful in determining the axis of a toric contact lens length and angle measurement is possible with a special eyepiece which is inserted instead of the standard eyepiece in the slit lamp tube and which is to be used with the magnification changer in a specific position.

The image scale in the eyepiece plane is then one. The eyepiece has a micrometer disk with linear scale of 15 mm with a scale interval of 0.2 mm. It also has an angle scale covering range of 180° with a scale interval of 2°. The artificial horizon required for measurement is produced by a gravity ball. When the eyepiece as a whole is rotated in the tube, the TABO angle of the diameter can be read on the right-hand side of the ball.

Ophthalmometry (keratometry) For this purpose an accessory ophthalmometer attachment is attached after the slit lamp illumination system has been swung to the side and the microscope objective removed with its dovetail guide. The attachment is then mounted. Such a combination of slit lamp and ophthalmometer will be of special interest to all those who can only occasionally need an ophthalmometer or have limited space.

Fundus observation with optical accessories Decribed in Chapter 9.

Slit lamp photography

Photography of Cornea and External Eye

Photodocumentation provides definitive reference for following progress of a disease as well as for

case reporting. Photo-slit lamp biomicroscope is able to reproduce the information seen at the clinical slit lamp. Alternatives include close-up systems based on single lens reflex cameras and photographic attachments to clinical slit lamps.

External photography Many external eye conditions do not need high magnification or the sophisticated illumination afforded by slit lamp and can be documented in a single-lens reflex camera (SLR) and macrolens. Focal length of 90 to 120 mm represent the ideal range to minimise the perspective distortion associated with lenses of shorter focal length. The macrolenses allow for focussing on closer objects. An electronic flash is needed to provide the necessary illumination. An electronic flash produces light of the correct colour temperatures for daylight film with enough energy to accommodate enhancement of depth of field. To correctly illuminate the eye at close range, the flash is mounted on the lens rather than on the camera body. A special flash mount, fitted to the filter threads of the lens itself, should be used. it further facilitates a 360 degree rotation of the flash around the lens for optimum control of shadows and highlights.

Photographic attachments to clinical slit lamp biomicroscopes consist of a 35 mm single lens reflex camera coupled with an adapter that takes the place of one ocular. Useful slit images are, however, difficult to record.

Photo-Slit Lamp Biomicroscope

Minimum components required are—(a) Beam splitter, (b) Electronic falsh, (c) Fill light.

A beam splitter provides the necessary coaxial view shared by the examiner and the film. It diverts from 50 to 85 per cent of the light to the camera to ensure satisfactory exposures with most forms of illumination. Electronic flash produces light of the intensity and colour temperature required to expose medium-speed, daylight-balanced film and an effective duration of exposure of about 1 ms, the speed required to arrest the motion of the eye at high magnification. The flash delivery system must be coaxial with the ambient light from the slit-beam illuminator. The fill light, an accessory source of diffuse illumination, provides partial compensation for the loss of the three-dimensional character of an examination.

KERATOMETRY

The anterior surface of the cornea acts like a convex mirror. This property is utilised in keratometry to determine the radius of curvature of anterior surface of cornea by the instrument keratometer. There are different models of the instrument and also different methods.

Keratometer

By the optics of this instrument, two mires are formed on the anterior surface of the cornea and observed through eyepiece. The mires are approximated and the reading is taken directly from the calibration of the instrument. Haag-Strait and Bosch and Lomb models are widely used in India. The description of method here will relate to these models (Fig. 4.30).

How to Use

Adjust the instrument Switch on the instrument. Move the eyepiece to extreme out towards you. Put a piece of white paper in front of the objective. Look with one of your eyes through the eyepiece and push the instrument forward till the black line is sharply focussed.

Put the patient Ask the patient to put his chin on the chinrest and the head on the headrest. Adjust the height till the outer canthus is in the same horizontal line of the notch, or black line of Haag-Strait or Bosch and Lomb model, respectively.

Cover one eye of the patient. Move the instrument vertically so that the objective is in the same line with the pupil. Ask the patient to look into the objective (Fig. 4.31, Plate 7).

Read the curvature Move the instrument slowly forward or backward as necessary till you get the clear image of the mires on the cornea.

By movement of the knobs and relating the instruments, mires are aligned both horizontally and vertically (Fig. 4.32, Plate 7). Now read out the curvature from the scale. Repeat the experiment at 90^{o} and also on the other eye.

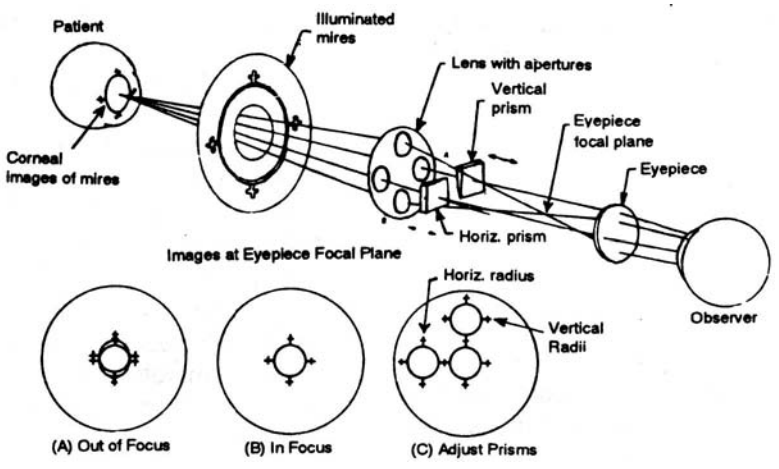


Fig. 4.30: Keratometer

The following notes are important:

1. Mires are irregular or broken in uneven corneas.
2. Mires may pulsate in kerotoconus.
3. Mires may not be formed in extreme corneal curvature changes.

EXAMINATION OF CONJUNCTIVA

The conjunctiva is in close proximation with the skin at the lid margin and nasolacrimal puncta. The conjunctiva is kept wet by the tear fluid and by secretions from the mucous cells of conjunctiva. The diseases of skin, mucous membrane, and abnormalities of tear secretion and drainage affect the conjunctiva. Hence, during the examination of conjunctiva these structures are also to be kept in mind.

METHOD OF EXAMINATION

A good source of light and a handheld magnifier are sufficient to examine the conjunctiva. Slit lamp may be rarely necessary.

Ask the patient to look straight. The palpebral aperture is exposed. Retract the lower lid by pulling down over the cheek. This will expose the lower fornix. By asking the patient to look down while you retract the upper lid, the upper bulbar conjunctiva is exposed. In the presence of blepharospasm and in children, an upper lid retractor to pull the upper lid is necessary.

To examine the upper tarsal conjunctiva, the upper lid is to be everted (Fig. 4.33). Ask the patient to look down. Pull the upper lid down after grasping the lid margin and lashes by thumb and index finger of your hand. Put a pencil horizontally at the upper border of tarsal plate on the skin surface of the lid with your other hand. Press the pencil a little, while you roll up the lid over it (Fig. 4.33).

Remove the pencil and the upper tarsal conjunctiva is exposed. To expose the upper fornix, double eversion is to be done on an upper lid retractor in place of the pencil.

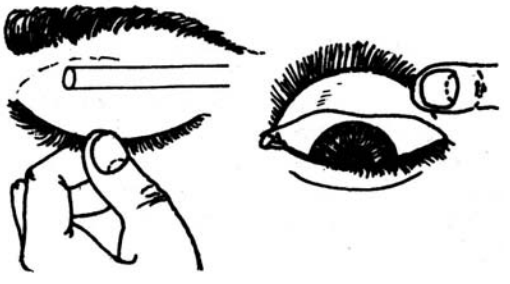


Fig. 4.33: Eversion of upper lid: While the patient looks down, pull the upper lid margin. Lightly press on the lid clearing the tarsal plate with a pencil and roll the lid on it

(*Note:* Do not use the upper lid retractor if keratomalacia is suspected. It may rupture the soft cornea.)

Points to Note

1. Redness
2. Watering
3. Discharge
4. Changes in the surface
5. New formation
6. Ulcers and granulomas

Redness Note the area, size, colour intensity of the redness. Conjunctivitis causes redness in the fornices (conjunctival congestion). Under magnification, dilated vessels are seen in the area of redness. The congestion due to pathology of cornea or uvea are present around limbus, and the vessels are seen running radially. The colour is bluish red (or pink). The conjunctival congestion can be reduced temporarily by weak (2.5% of 5%) phenylephrine drops but deep episcleral vessels' congestion cannot be reduced this way. The red colour of subconjunctival haemorrhage is bright, the vascular dilatation is absent and cannot be reduced by phenylephrine. The size of subconjunctival haemorrhage may be small as a pinhead in viral conjunctivitis to large blot as seen in whooping cough in children.

Palpate the preauricular lymph node. It becomes enlarged and tender in some conjunctivitis, e.g. adenoviral on chlamydial infections.

Search for pannus in superior limbus in chronic conjunctivitis or if trachoma is suspected. Pannus is also found in vernal conjunctivitis and phlyctenular conjunctivitis. It is seen as a leash of straight blood vessels invading the cornea from this limbus.

Watering Note the following:

a. Whether the nasolacrimal puncta is patent and in contact with the lacrimal lake? Mild ectropion displaces this puncta thus hampering this normal draining.
b. Exclude pathology of lid, cornea, and uvea. Corneal ulcer or foreign body, acute iritis causes watering. Entropion and misdirected lashes rub on the cornea causing reflex watering.
c. Test the nasolacrimal pathway. A frank regurgitation on pressing over the sac area will prove blockage of the pathway.
d. Perform the Schirmer's test

A filter paper strip (Whatman No. 41) of 5 mm width and more than 30 mm length is folded at one end and put in the lower fornix, this small folded end kept in the fornix while the rest hanging over cheek. Patient closes the eye and the time noted. Less than 5 mm wetting proves poor tear secretion and more than 30 mm indicates increased reflex tearing (Fig. 4.34).

Discharge The quality of discharge has some diagnostic significance. It is watery in viral conjunctivitis mucoid and can be drawn into a string in allergic conjunctivitis, mucopurulent in bacterial conjunctivitis and frank pus in gonococcal conjunctivitis of the newborn.

Changes in the surface The most important surface change is foamy appearance in a triangular area with base towards the limbus. The foamy triangular area is situated in the palpebral apperture. Vitamin A deficiency results in such spot and is termed as Bitots' spot. In children cases of fine cracks and dusty colour appear in the conjunctiva which looses its normal lustre. Application of *kajal* may change the colour of spot to dark gray.

Corrossive liquids or Stevens-Johnson's syndrome causes change resulting in scar tissue

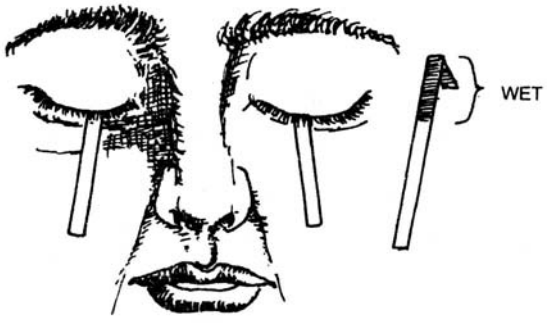


Fig. 4.34: Schirmer test: With 5 mm wide and 30 mm long filter paper strip. Note that eyes are to be kept closed for 5 min and measure the wetting from the fold

formation and sometimes adhesion between bulbar and tarsal conjunctiva called symblepharon.

A triangular fold of conjunctiva in the palpebral aperture with apex at the cornea is a degenerative change termed as pterygium.

New formations Follicles, papillae, pinguecula, phlycten and tumours are to be noted.

Follicles: These are small elevations with aggregation of lymphoid tissue. In association with conjunctivitis they are significant.

Papillae: These are larger elevations.

Cobble stone appearance with milky white colour is typically seen in spring catarrh on upper tarsal conjunctiva.

Pinguecula: Small white elevations usually found in older age group is a degenerative change.

Phlycten: These are small pinkish white elevations in the conjunctiva in and around limbus, sometimes with ulcer in the centre.

Tumour of conjunctiva are the commonly found at limbus. Dermoids are most common. Carcinomas are infrequent.

Ulcers and granulomas These are rare. Syphilitic gummas and tuberculous ulcers were common in the past. Caterpillar hair causes a granulamatous reaction around it in conjunctiva—ophthalmic nodosa. A granulomatous growth which bleeds easily and is attached to the conjunctiva by a stalk is often proved as rhinosporidiosis.

Laboratory Work-up

When a patient presents with a red eye, laboratory tests may give information that helps in a more specific diagnosis. The clinician can complete some of these tests in the clinic while trained personnel completes other procedures in the laboratory. Microscope slide examinations and cultures are the most common tests.

Culture of organisms The clinician inoculates eye material on culture media and sends the media to a microbiology laboratory for incubation and identification. This method is time-consuming. Cultures provide definite identification of bacteria and fungi. Cultures also identify Chlamydia, viruses and Acanthamoeba organisms.

Direct observation of the specimen Microscope slide smears can provide identification of the types of cells or micro-organisms present. Eye specimens on slides are immediately air dried or fixed in alcohol. Specific stains help identify specimens, e.g. Gram's and Giemsa's stain tests. Gram's stains are used to presumptively identify and classify bacteria. Gram's stain results help the clinician decide upon an antibiotic. Giemsa's stains are used to identify the type of inflammatory cells present. Based on the type of inflammatory cells the clinician can presumptively determine the cause of an inflammation (bacterial, viral, or allergic). Additional slides are prepared and send to the laboratory for confirmation of the results and also in difficult cases including corneal ulcers. Direct slide tests involve simple and quick methods, though they are usually less reliable than those obtained by culture excepting direct fluorescent antibody (DFA) test, which is specific and sensitive in detecting Chlamydia and certain viruses. DFA stains use monoclonal antibodies prepared against antigens present on an organism. The antibodies, with fluorescent tags, have an affinity for finding only with proteins specific for the organism.

Other tests Recent methods including limulus lysate test, enzyme immunoassay, electron microscopy with negative staining, and nucleic aic hybridisation techniques provide sensitive and specific results in less than four hours. Excepting enzyme immunoassay (EIA) all these tests are expensive and not widely available. EIA diagnoses Chlamydia and viral infections, e.g. HSV (1 and 2) and adenoviruses rather quickly.

Cultures, Gram's stains and cytology stains (Giemsa or Diff Quick) provides information about a conjuctivitis or keratitis. DFA smears, special tests and enzyme immunoassays provide more specific or definitive informations than Gram's stain and cytology stains. However, Gram's and cytology tests are usually the only tests completed in the clinic.

Special stains are used to identify fungi, certain bacteria (e.g.) *Mycobacterium tuberculosis)* and Acanthamoeba.

Indications for Laboratory Work-up

1. Central corneal ulcers or any ulcer that is possibly infectious.
2. Any severe long-standing conjunctivitis.
3. A hyperacute or membranous conjunctivitis.
4. A postoperative infection or abscess.
5. Conjunctivitis in a newborn.
6. Any case with unusual signs or symptoms.
7. A conjunctivitis not responding to treatment.
8. Sudden change in appearance of an ulcer under treatment.
9. Allergic or vernal conjunctivitis.

Sequence of Work-up

A. Cultures and smears are taken before commencement of the treatment.

Cultures Conjunctival and lid cultures are prepared before gram stain and cytology smears, and before instilling drops into the eye. Corneal culture are taken after lid and conjunctival cultures.

EIA tests Swab specimens for EIA tests are taken after cultures and before slide preparations. Then swabs for Chlamydial and viral cell cultures are taken.

Specimens For preparing slides (Gram's Cytology, DFA and special stains) specimens are taken after corneal ulcer culture specimens. In case of small corneal ulcers, smears for gram's stains are taken before culturing to increase the recovery of organisms in the smear.

If a patient is already on antibiotics and the conjunctivitis is not severe, antibiotics should be discontinued for 24 hours before taking the cultures.

Corneal Ulcer Work-up

1. To obtain a culture from the lids and conjunctiva of both the infected and the noninfected eyes, calcium alginate swabs moistened with nutrient broth should be used. Cotton swabs are not preferred as they contain fatty acids that have inhibitory effect on bacterial growth. Topical anaesthetics should be better avoided as the preservatives may act as bactericidals if they contaminate the culture specimen. The entire cul-de-sac should be wiped and the material streaked on a blood agar plate. The same method is repeated for the lid margin.
2. The eye is anaesthesised with proparacaine, HCl, which is least bactericidal. A dry swab is used to remove superficial debris from the ulcer and then the same blood agar plates used for lid and conjunctival cultures are inoculated with these debris.
3. A sterile kimura spatula (or other devices including a number 57 Bard Parker blade, or hypodermic needle may be substituted) is used to scrape the edge and the base of the ulcer. The spatula is heat sterilised in a burner before using. Direct visualisation of the ulcer with the slit lamp should be done to confirm the presence of material on the end of the spatula. The specimen material is C-streaked on a blood agar plate. Further specimens are obtained for inoculation of chocolate agar and Sabourand agar. Any growth on the C-streak may be roughly considered meaningful whereas any growth off the C-streak is considered a probable contamination. The Sabourand agar should be made up without cycloheximide (toxic to saprophytic fungi) if fungal infection is suspected. If Sabourand agar is not available, a blood agar plate is used and incubation done at room temperature. A chopped meat i.e. glucose broth should be inoculated whenever anaerobic pathogens are a possibility. This glycolate medium with hemin and vitamin K may be an alternative.
4. Finally, multiple specimens obtained are spread on slides for Gram's Giemsa, and other stains.

An additional slide may be prepared by placing the material in a drop of 10 per cent potassium hydroxide. A cover slip is placed on this preparation and the slide is examined for fungal filaments under low and high magnification of the microscope. Potassium hydroxide helps in clearing the tissue material and rendering the filaments more

prominent. Yeasts can be missed in this preparation.

After taking smears they are air dried. Air drying causes a ballooning-up of the cell. The nucleus, cytoplasm and intracytoplasmic inclusions become enlarged and are easier to identify. Some smears are fixed in absolute methyl alcohol after they are air dried. Other smears are fixed immediately after they are taken. Gram's and Giemsa's stains should be air dried and then fixed in methanol. DFA smears are air dried, then flooded with methanol, which is allowed to evaporate. Periodic acid-shiff (PAS) slides are fixed in methanol immediately before they dry. Fixation stabilises cellular components, preserves cell structure, and stops all biochemical and mechanical activity. Smears that are fixed immediately have cells that are not "ballooned-up". Improper heat fixation may damage cells and cause Gram-positive micro-organisms to appear Gram-negative. For this reason, fixation with absolute methyl alcohol is the recommended method.

Impression cytology It is a simple, painless nontraumatic procedure. Cellulose acetate filters are pressed against the patient's conjunctiva to pick up surface cells. By this technique, it is possible to sample different conjunctival areas. This technique is used to evaluate ocular surface epithelial changes in conditions including keratoconjunctivitis sicca, xerophthalmia, allergy, anorexia nervosa, long-term use of ocular medications, etc.

Procedure Usually the inferior bulbar conjunctiva needs to be sampled; the superior, nasal and temporal conjunctiva may also be sampled for a more detailed study. A drop of topical anaesthetics is instilled in the eye (preferably 0.5% proparacaine). A cellulose acetate filter is gently placed to the selected conjunctival area with the duller side against the eye. The filters can be cut to any size but are easier to handle if at least 6 mm in diameter. Light pressure is applied to the filter with the blunt end of a glass rod for 3 to 5 seconds and then removed with a peeling motion. The filter is attached to the slide using stainless stell clips. The slide is fixed in 95 per cent ethyl alcohol for 15 minutes and then stained. The stain used depends on the purpose of the test. For dry eyes PAS and hematoxylin stains are used (Table 4.2).

Table 4.2: Staining procedure for Gram's and Giemsa's stains

Air dry the slide ↓ Fix slide in absolute methyl alcohol ↓ Air dry the slide	
(For Gram's stain)	(For Giemsa's stain)
Flood slide with crystal violet solution for one minute. Rinse gently with tap water ↓	Place the slide in Giemsa's solution for 45 minutes ↓
Flood slide with iodine solution for one minute. Rinse gently with tap water ↓	Rinse quickly in 2 changes of 95 per cent ethyl alcohol ↓
Tilt slide to decolourise, allowing decolourising solution to run over the slide unit it is colourless ↓	Air dry the slide.
Flood slide with safranin stain for one minute. Rinse gently with tap water ↓	
Air dry the slide	

The Gram's stain divides most bacteria into Gram-positive and Gram-negative types based on structural difference in their cell walls. It shows the shape and arrangement of individual bacterial cells. Gram's stain in useful in identifying bacteria, most fungi and yeasts, and Acanthamoeba cysts, but it provides no information about inflammatory or epithelial cells. In some cases Giemsa's and PAS stains are more useful in fungal identification.

Bacteria are usually spherical (cocci) or rod-like (bacilli) in shape and can vary in size. Cocci arrangements are in pairs (diplococci), in chains

Table 4.3: Morphology and Gram's stain reactions of common eye bacteria

Types of cocci	*Forms and shapes*
Gram-negative Cocci	
Neisseria gonorrhoeae	Diplococci, often intracellular in polymorphs.
Gram-positive Cocci	
• *Staphylococcus aureus*	Cocci in clusters, Occassionally single or in pairs
• *Staphylococcus epidermidis*	Cocci in clusters, occassionally single or in pairs
• *Streptococcus pneumoniae*	Diplococci (lancet-shaped), occassional small chains
• Streptococcus species	Cocci in short chains. Occassionally single or in pairs.
Gram-negative rods shaped	
• Pseudomonus aeuruginosa	Slender rods
• Haemophillus species	Small rods, or coccobacilli]
• Moraxella species	Diplobacilli, small dumbbell-shaped; or small cocci
• Serratia marcescens	Small rods, or coccobacilli.
Gram-positve rod-shaped	
Corynebacterium species	Rods with bent or irregular shape
(Gram stain results are used to select an initial antibiotic for a keratitis).	
Gram-positive cocci	Cefazalin, vancomycin or bacitracin and gentamicin
Gram-negative cocci	Penicillin G, or bacitracin
Gram-positive rods	Cefazolin, gentamicin or penicillin G
Gram-negative rods	Gentamicin (tobramycin), or Carbenicillin
No organisms but clinical suspicion	Bacitracin and gentamicin, or cefazolin and gentamycin (tobramycin)
Two or more bacteria	Cefazolin and gentamicin
Yeast, psendohyphae, hyphae	Natamycin, amphotericin B, or miconazole.

(streptococci), or clustures (staphylococci). Bacilli occur singularly, in pairs, or in chains. Greater morphological variation occurs among fungi than bacteria (Table 4.3).

Cytology stains are used to identify the following:

a. the types and relative numbers of inflammatory cells present.
b. epithelial cells and single cells or groups of cells
c. the most fungi and yeast
d. intranuclear viral inclusions and other morphological changes associated with viral infections
e. chlamydial inclusions
f. the presence of bacteria.

The Giemsa's stains must be freshly prepared before use and staining takes about one hour.

Cell Types Found in Cytology Stains

1. *Epithelial cells*
   a. Corneal cells.
   b. Conjunctival cells—(i) Nonsecretory conjunctival cells, (ii) Goblet cells.
2. *Inflammatory cells*
   Neutrophils (polymorphs), lymphocytes, macrophages, eosinophils, basophils, plasma cells, and mast cells.
3. *Micro-organisms*.
4. *Other materials*—mucous, fibrin, degenerative cellular debris.

Cell identification It is based upon the size, morphology of single cells, the tendency to form clusters or sheets, and staining characteristics as discussed below:

1. Cell size can be determined by comparing a cell with one of known size. Neutrophils

(10 μm) are easy to recognise and can be used as a comparative standard for estimating the relative size of another cell. Epithelial cells (15-40 μm) can be identified at 100x magnification whereas 1000x is needed to identify bacteria (1-3 μm).

2. Morphological examination include the shape of a cell's nucleus and cytoplasm and the amount of cytoplasm. Distinguishing cytoplasmic features include granules, vacuoles, or phagocytised material.
3. Examination of the arrangement of the cells may show clusters or sheets formation in case of corneal and conjunctival epithelial cells whereas inflammetory cells are usually single, though they may overlap at times.
4. Variations in staining intensity and colour are very helpful, e.g. pinkish red cytoplasmic granules help identify eosinophils.
5. Scraping from normal eyes shows epithelial cells with rare lymphocytes, polymorphs or bacteria. Normally conjunctival epithelial cells are in clusters or sheets but epithelial cells in a case of conjunctivitis are more often single. The number of inflammatory cells is more in inflamed eyes with associated tissue necrosis. Exudative smears in conjunctivitis may be rich sources of neutrophils or eosinophils. The presumptive cause of a conjunctivitis may be determined by the numbers and types of cells present:
   - Basophils—allergic conjunctivitis, vernal conjunctivitis
   - Eosinophils—allergic conjunctivitis, vernal conjunctivitis
   - Intracytoplasmic inclusions—Chlamydial conjunctivitis, viral conjunctivitis
   - Intranuclear inclusions—viral conjunctivitis
   - Lymphocytes (main response)—viral conjunctivitis, chronic drug-induced conjunctivitis
   - Macrophages, large (Leber cells)—Chlamydial conjunctivitis
   - Mast cells—vernal conjunctivitis, giant papillary conjunctivitis
   - Plasma cells—Chlamydial conjunctivitis, vernal conjunctivitis
   - Polymorphs (main response)—bacterial conjunctivitis, allergic conjunctivitis, drug-induced conjunctivitis, fungal conjunctivitis, early adenoviral conjunctivitis
   - Polymorphs and lymphocytes—Chlamydial conjunctivities, herpes zoster conjunctivitis.
6. Fungi may be seen in eye scrapings, and Gram's and cytology stains can provide an immediate diagnosis. Occassionally, special stains are needed.

   Fungi causing eye disease may be of two basic types—filamentous and yeasts.

   Filamentous fungi may be of two types—septate (having septa dividing the hyphae into "cells" and nonseptate. Septate fungi are nonpigmented or pigmented.

   Yeasts are oval to spherical cells. Dimorphic fungi show both yeast and hyphal forms depending upon culture conditions. Yeast infection usually occurs in compromised patients, while filamentous fungi can cause infections in healthy patients exposed to trauma.

   Filamentous fungi found in eye disease include the pigmented septate fungi—Alternaria and Curvularia, and the nonpigmented septate fungi—Aspergillus, Cephosporium, Fusarium, and Penicillium. Yeasts include Candida and Cryptococcus, Dimorphic fungi include Blastomyces and Coccidioides.

   Both Gram's and Giemsa's smears can show hyphae and yeasts.
7. Acanthamoeba, an amoeba found in fresh water, can exist in either a cystic (protective) or trophozoite form. Since both forms are shed from the corneal surface, it is possible to make a presumptive diagnosis from ulcer scrapings. Cystic organisms appear as clear, refractile, round bodies with Giemsa's staining. Trophozoites are larger than neutrophils and have a small round nucleus that is centrally placed in abundant cytoplasm. Trophozoite form can be difficult to identify with Giemsa's stains and indirect fluorescent antibody stains are needed for a specific diagnosis.

8. Keratinisation of the epithelium occurs in dry eye and vitamin A deficiencies and is diagnosed by impression cytology. Squamous metaplasia, a pathological change of epithelial cells to nonsecretory and keratinised cells, occurs in dry eye, ocular pemphigoid, anorexia nervosa and in chronic use of ocular medications.

EXAMINATION OF SCLERA

The white sclera is visible through conjunctiva. It is bluish white in newborn. Dark small points on the sclera are the points of perforation of scleral vessels and are of no significance. During the examination of sclera note the following.

1. *Colour Blue* sclera is present in osteogenesis imperfecta, where a history of recurrent fracture of bones is obtained. Deafness may be present.

   Localised ectasia of sclera with prolapse of uveal tissue seen as dark blue area in staphyloma and sclero malacia perforance.

2. *Congestion* Scleral and episcleral congestion (Fig. 4.35, Plate 7) is seen as bluish red (pink or purple) meshwork of dilated vessels. Weak phenylephrine solutions cannot constrict the vessels.

3. *Pain and tenderness* This is almost always present in the inflammation of sclera except in scleromalacia perforance.

4. *General history and systemic examination* It may reveal collagen diseases and tuberculosis which are commonly associated with scleritis (Fig. 4.35, Plate 7).

Chapter 5

Examinations of Uvea and Lens

EXAMINATION OF UVEA

Uveal diseases range from congenital abnormalities through inflammation to malignancies. A good history and meticulous examination is aimed at proper diagnosis and preferably the aetiology of the disease.

Present History

Chief complaints Common presenting symptoms are usually the following:

a. Pain
b. Redness
c. Photophobia
d. Watering

} Anterior uveitis

e. Diminished vision
f. Floaters

} Posterior uveitis and intermediate uveitis

The first five symptoms show anterior uveitis whereas diminished vision and floaters alone express posterior and intermediate uveitis, respectively.

Mode of Onset

Acute With severe pain and photophobia with some reduction of vision in acute anterior uveitis, little or no pain, minimum photophobia and blurring in posterior uveitis. Examples of acute anterior uveitis are Behcet's diseases, viral (herpetic) Keratouveitis, Reiter's syndrome, Fuch's heterochromic iridocyclitis. Examples of acute posterior uveitis are symathetic ophthalmia, Vogt-Koyanagi-Harada's syndrome, toxoplasmosis, acute posterior multifocal pigment epitheliopathy.

Chronic Presents with insidious onset, longer duration, gradual loss of vision, mild pain. Usual causes are tuberculosis, sarcoidosis, juvenile rheumatoid arthritis, fungal endophthalmitis, etc.

Past History

Past history of such attack, herpetic infection of the eye, surgery on the eye are important.

General History

Search for any history of tuberculosis, sarcoidosis, leprosy, toxoplasmosis, sinusitis, urethritis, rheumatoid arthritis, sacroileitis, malignancies like lymphoma and chemotherapy; note also other causes of immunosuppression including AIDS. Also note if there is history of diabetes.

Geographic History (Table 5.1)

Table 5.1: Deseases and their locations

Diseases	*Locations*
TB, Syphilis, Leprosy	India, Africa
Vogt-Koyanagi Harada's disease	Japan
Behcets' disease	Japan, Mediterranian countries
Histoplasmosis	Ohio, Missouri, Mississippi, Histoplasma belt.

Family History

Collagen diseases, toxoplasmosis, syphilis, tuberculosis, CMV and AIDS.

Age and Sex

Uveitis is more common in young adult and middle ages. Age-related uveal pathologies may be grossly classified as the following:

Congenital Colobomas of iris, ciliary body and choroid, congenital toxoplasmosis.

Young children Embryonal medulloepithelioma, toxocariasis, juvenile rheumatoid arthritis.

School going children Juvenile rheumatoid arthritis, toxocariasis, leukaemia, essential atrophy of iris.

Adults and middle aged Ankylosis, spondylitis, Behcet's disease, VKH, AIDS, syphilis, malignant melanoma, idiopathic uveitis.

Old Aphakic uveitis, Masquerede's syndrome, herpes-zoster, idiopathic uveitis. Choroidal degenerations occurs in middle aged and elderly.

More common in male Reiter's disease, ankylosing spondylitis, Behcets' disease, sympathetic ophthalmia.

More common in females Juvenile rheumatoid arthritis, toxoplasmosis.

EXAMINATION OF EYE

Vision

It is important to note distant and near vision with and without glass and also with pinhole. Vision should be recorded at each visit. Snellen's test type is commonly used, but ETDRS test type is more sensitive to record minute changes. Poor accommodation may be an early sign of sympathetic ophthalmia.

Lid and Skin Around Eye

Search for vitiligo, poliosis, herpetic lesion of scar of it, alopecia, acne, etc. Sometimes skin of the whole body needs to be examined.

Intraocular Pressure (IOP)

It must be noted in every case of suspected uveal pathology and also in follow-up. IOP may be raised in the following conditions:

- Sturge-Weber syndrome
- Uveal tumour
- Abnormality at anterior chamber angle in anterior uveitis
- Essential atrophy of iris.

IOP may be reduced in late stage of anterior uveitis due to inflammed or atrophic ciliary secretory epithelium.

Examination of Pupils

Swinging flash light test It is performed for afferent pupillary defect. In the event of synechia it is difficult to properly examine.

Size Very small or miotic in iritis. Very large in aniridia.

Shape Irregular if posterior synechia; D-shaped in iridodialysis. Note that the shape of pupil may be altered by prior surgery. Posterior synechia around pupillary margin may prevent normal flow of aqueous and push iris forward-iris bombe.

Direct reaction to light Usually sluggish in iritis, may be absent in fixed posterior synechia or in blind eye.

Number Polycoria is typically found in essential atrophy of iris. Peripheral iridectomies (see Fig 8.16, Plate 18).

Slit Lamp Examination

A detailed examination of all ocular structures is essential, not only the uvea.

Conjunctiva and sclera Note any congestion. A circumcorneal injection is common in anterior uveitis. The congestion is diffuse, whereas localised congestion and purple hue is found in scleritis. The congestion should be graded from 0-4 for future follow-up.

Please note any nodules, phlycten, ulcer, congestion if any found on conjunctiva.

Cornea Search for any lesion on cornea. Keratitis in any form—punctate, disciform, interstitial, frank ulceration, dendritic or pseudodendritic are to be noted. Note any vascularisation also.

Superficial lesions of cornea are examined by broad beam at 30° to 45° angle and the deeper stromal lesions at almost 90°. Band keratopathy is seen in chronic iridocyclitis particularly in children. Its distribution is in interpalpebral zone with a clear zone separating the band from limbus.

Keratic precipitates (KP) are the most common findings in anterior uveitis. Distribution of KP is important. They are commonly located in mid and

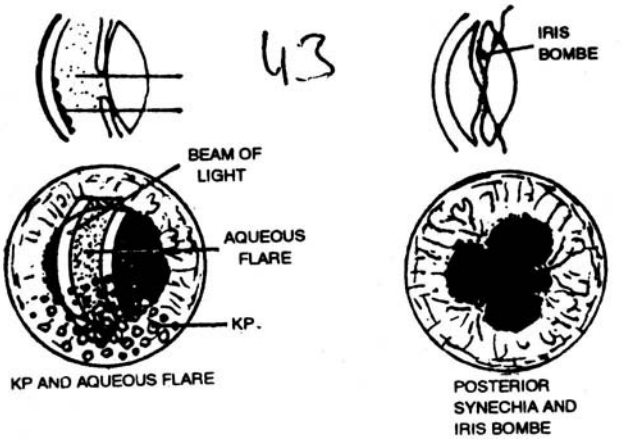


Fig. 5.1: Keratic precipitation and aqueous flare. Posterior synechia and iris bombe

inferior zones of cornea in the shape of a base down triangle on the endothelium. These are small aggregates of inflammatory cells. KP in a quiet eye indicates uveitis in the past (Fig. 5.1).

Corneal dendrites are present in herpetic keretouveitis. Hazy cornea from interstitial keratitis may be found in syphilis and sometimes in keratouveitis. Corneal oedema and folds may be present in postoperative endophthalmitis.

Anterior chamber Note contents and depth of anterior chamber in detail.

Contents of anterior chamber

By using slit lamp the cells and flares may be detected. Gonioscopy may detect small amounts of abnormal contents as well as other disturbances.

Cells Presence of inflammatory cells can be detected by throwing the slit beam obliquely across anterior chamber and focussing posterior to cornea in mid anterior chamber. Light intensity and magnification must be maximum. The slit beam should be 1 mm x 3 mm. The actual number of cells are to be counted for grading (Table 5.2).

Method of grading used are different at different centres. Whatever method is used, that should be strictly followed.

The anterior chamber cells are mainly lymphocytes and plasma cells. They are seen as small, spherical glistening nonpigmented cells. Sometimes larger macrophages are seen more when they ingested blood or melanin pigment granules and cells are detected by colour and small size. The average size is to be noted.

Table 5.2: Number of cells and grading

Cells per field	*Grades*
0	–
1-5	±
6-10	+
11-20	++
21-50	+++
Over 50	++++

The number of cells as well as the size of the individual cells decrease as the uveitis resolves.

Aqueous flare In a smoky room the beam of a flash light is visible. In the same way the path of slit beam is visible if the protein content of the aqueous increases. It also indicates break down of the blood~aqueous barrier. The flare is graded clinically and used as an index of inflammation. The beam should be thrown obliquely to the plane of iris, in order to detect the degree of obscuration of iris details and lens (Table 5.3).

Fluorophotometer more accurately quantifies the amount of protein present in anterior chamber. The fluorescein dye in anterior chamber binds to

Table 5.3: Clinical grading of flare

Grades	*Description*
0	Complete absence
+	Faint-barely detectable
++	Moderate-iris and lens details clear
+++	Marked-Iris and lens details hazy
++++	Intense-fixed coagulated aqueous with considerable fibrin.

albumin in anterior chamber. It alters the polarisation of fluorescein, the degree of which is recorded as a quantitative measure of break down of blood—aqueous barrier.

Laser flaremeter records the amount of scattering of projected laser beam by the contents of anterior chamber. This also is recently being used as an index of flare.

Hypopyon A whitish exudate on the dependent part of anterior chamber essentially containing polymorphonuclear leucocytes and fibrin, is called hypopyon (pus in anterior chamber). It is classically seen in Behcets' disease and infective endophthalmitis.

Hyphaema Blood in anterior chamber or hyphaema found commonly in gonococcal and syphilitic anterior uveitis, ophthalmia nodosa from caterpillar hair, and trauma.

Depth of anterior chamber (Figs 5.2 and 5.3)

- Deep and irregular in posterior synechie
- Funnel shaped in iris bombe
- Shallow in anterior synechia.

Iris A detailed examination to note the following:

i. *Muddy iris* The brightness of iris is lost, the crypts poorly defined and the iris looks thick.

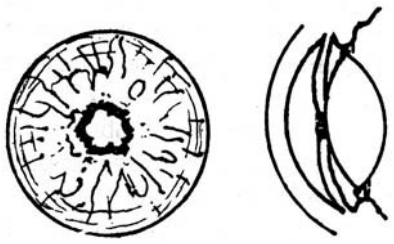


Fig. 5.2: Occlusio pupillae

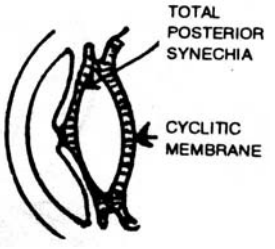


Fig. 5.3: Posterior synechiae

ii. *Nodules* Present at pupillary margin are Koeppe's nodules commonly seen in granulomatous uveitis and sometimes in nongranulomatous ones. Busacca's nodules are situated away from pupil and seen in granulomatous uveitis only.

iii. *Cysts, naevus, tumour* Cysts are translucent swellings on iris usually distorts the pupil and commonly found after intraocular surgery. Naevus is usually congenital and abrupt change is noted. Any visible growth on iris must be recorded.

iv. *New vessels or rubeosis* Search at area little away from pupillary border, iris crypts and angle of anterior chamber. These are usually found in long-standing ischaemic retinopathies e.g. proliferative diabetic retinopathies, central retinal venous occlusion, chronic cyclitis, chronic anterior uveitis and Fuch's heterochromic cyclitis.

v. *Gonioscopy* Examination in details of the anterior chamber angle is a must in examination of uvea. The method of gonioscopy is described in Chapter 6. The important points to note are peripheral anterior synechia (PAS)—any membrane, new vessels, foreign body, congenital abnormalities, etc. The depth of anterior chamber also is assessed during gonioscopy and a goniogram is constructed.

vi. *Common signs* Lens is to be examined for cataract, pigments on anterior capsule and fibrovascular membrane on pupillary area. These are common signs in anterior uveitis of moderate to long duration.

vii. *Examinations of choroid and pars plana* These examinations are done by direct and indirect ophthalmoscopy, Hruby lens as well as 3-Mirror lens and 90-D lens. The techniques of examination are as described in the chapter on examination of retina and vitreous. Here the point to note are summarised.

Congenital abnormality Coloboma of choroid usually seen as a defect shaped as or the apex being at or near the disc. In most cases it is associated with coloboma of iris which is seen as a defect of pupil. The lower margin of pupil is absent and the pupil is pear-shaped.

Macular changes Cystoid macular oedema may be associated with uveitis—mainly pars planitis. It is also found after anterior segment surgery, Hruby lens mounted on slit lamp and a well-dilated pupil are usually sufficient to detect cystoid macular oedema, and other macular changes. The stereoscopic advantage of slit beam helps differentiate macular cyst from hole. The slit beam is slowly moved from one side over the macular region to detect changes or abnormalities of macula. At the same time the optic disc also is evaluated for colour, cup/disc ratio and vessels at or near the disc. Secondary glaucoma from uveitis or steroid used to treat uveitis should be detected. Otherwise the result of treatment of uveitis may be a quiet but blind eye.

Pars plana is best seen by indirect ophthalmoscopy with scleral depression. Snow banking of pars planitis is usually seen in lower part around six O'clock position. 3-mirror lens also is used to visualise pars plana. It also can be used with addition scleral depressor. Though this lens needs slit lamp and topical anaesthesia, and thus a little cumbersome, it helps in detecting traction bands, vitreous cells and midperiphery of vitreous, retina and choroid.

A general look of the retina, vascular changes like sheathing, retinal and choroidal oedema, pigment clumping, cotton wool spots and splinter haemorrhages can be detected on the slit lamp by a 90 D lens or 78 D lens, or indirect ophthalmoscope alone. These features are quite common in posterior and intermediate uveitis.

Active retinal infiltration is accompanied by vitreous cells, surrounding retinal oedema and are best seen under 3-mirror lens. Direct ophthalmoscope is sufficient to detect these lesions posteriorly.

viii. *Examination of the optic nerve* This should be done before completing examination of uvea. There may be a visual loss from damage to optic nerve. Optic atrophy, cupping, papilloedema or papillitis, sheathing of vessels of disc and new vessels are to be noted. Direct ophthalmoscope. Hruby lens on slit lamp or a 90 D or 78 D lens is sufficient to evaluate optic nerve clinically.

ix. *Photostress test and Amsler grid charting* In all cases where macula is involved, these should be recorded in every visit.

Photostress Record the vision of an eye completely covering the other. Shine a light of pen touch from 5 inches for 20 seconds on the eye. Now ask to read the chart. Note how much time is needed to recover the vision recorded before shining the light. Repeat the test in other eye.

Amsler grid It records any subtle changes of central vision. Details of recording is described in Chapter 6 on Glaucoma under Field test.

SYSTEMIC EXAMINATION

A general systemic examination should be done in affections of uvea, mainly uveitis. A list of common systemic findings in uveitis is noted in Table 5.4.

Laboratory Investigations

Common laboratory investigations may be ordered as follows:

A. *In Iridocyclitis*
   I. In children (less than 15 yrs):
      a. ESR

Table 5.4: Common systemic findings in uveitis

Features	*Diseases*
Alopecia	VKH syndrome, sympathetic ophthalmia, secondary syphilis
Poliosis	VKH syndrome, sympathetic ophthalmia
Skin rash	Secondary syphilis
Erythema - nodosum	Sarcoidosis, Behcet's disease
Psoriasis	Psoriatic arthritis
Keratoderma blenorrhegica	Reiter's syndrome
Lupus pernio	Sarcoidosis
Pitting of nails	Psoriatic arthritis
Dystrophy of nails	Reiter's syndrome
Painful ulceration of mouth	Behcet's syndrome
Arthritis	Spondyloarthritides, Juvenile chronic arthritis, sarcoidosis
Gut involvement	Ulcerative colitis, Crohn's disease, Whipple's disease
Lung involvement	Sarcoidosis, tuberculosis
Urethritis	Reiter's disease, gonorrhoea
CNS involvement	VKH syndrome, congenital toxoplasmosis, Behcet's disease, reticulum cell sarcoma.

b. Antinuclear antibody (ANA) titre
c. VDRL
d. Fluorescent treponemal antibody absorption (FTA-Abs) test
e. PPD (Mantoux) test
f. X-ray chest
g. X-ray knee.

II. In adults:
a. ESR
b. Chest X-ray to rule out pulmonary tuberculosis and sarcoidosis
c. Skin tests for anergy (mumps, trichophyton) and sarcoid
d. PPD for tuberculosis
e. VDRL and FTA-Abs for syphilis
f. HLA-B 27 for ankylosing spondylitis and Reiter's syndrome
g. Sacroiliac joint X-ray.

B. *In chorioretinitis*

I. In children (less than 15 yrs):
a. Chest X-ray and PPD for TB
b. Toxoplasma serology
c. Toxocara (ELISA test)
d. Investigation for sarcoid.

II. In adults:
a. Chest X-ray and PPD
b. Toxoplasma serology
c. VDRL/FTA Abs.

Other Investigations

1. HLA
   - HLA-B 27 — Ankylosing spondylosis, Reiter's syndrome, juvenile rheumatoid arthritis.
   - HLA-B 5
   - HLA-4 C — Behcet's syndrome
   - HLA-B 7 — Histoplasma
   - HLA-DRWS — Histoplasma
   - HLA-BW 22 J — VKH syndrome
   - HLA-A 29 — Birdshot chorioretinopathy.
2. Rheumatoid arthritis factor (RA) in adult rheumatoid arthritis.
3. Toxoplasma dye and indirect fluorescein antibody test and haemagglutination test—toxoplasmosis.
4. Histoplasma skin test.
5. Serum lysozyme—in active systemic granulomatous uveitis.
6. Angiotensin converting enzyme (A/E) and gallium scan test for active sarcoidosis.
7. Estimation of acute phase proteins in serum:
   a. alpha-1 Antitrypsin
   b. alpha-2 Macroglobulin, factor B, C-reactive proteins, ceruloplasmin, fibrinogen.

There is a rise to these proteins in acute bacterial infections, acute rheumatic fever, malignant disease, retinal vasculitis, acute endogenous uveitis.

Recent Investigations

Recently some clinical investigations have been introduced in practice. These have proved of immense help in diagnosis and follow-up of uveal diseases.

Laser flare-cell meter It has been developed under leadership of Prof Kanjiro Masudo of Japan.

Use Quantitative measurement of cells and protein concentration of anterior chamber. Thus accurate assessment of inflammation and response to treatment is posibile. It is a great tool in assessing and treating anterior uveitis.

Principle A weak He-Ne laser beam is projected to an window area of 0.3 m x 0.5 m in mid anterior chamber. The light is scattered and reflected by cells and proteins in the anterior chamber. This light signal is picked up by a photomultiplier and a computer calculates the scattered light intensity and finally shows the intesity of flare and number of cells in the window.

The instrument is used as a slit lamp, the light being a little brighter. The procedure is noninvasive and safe for the patient.

Ultrasound biomicroscopy This technique of using ultrasound was first published by Parten, Sherer and Foster in 1990. This technique can produce microscopic images in living eye. The areas clearly imaged are iris and ciliary body including angle structures and pars plana up to a depth of 4 mm. The resolution is up to 20 micron.

Clinical use

i. Identification and follow-up of growth, etc. of iris, cysts and tumour of iris, ciliary body and anterior choroid.
ii. Visualisation of angle structure and deformities in the presence of the hyphaema and opaque cornea.
iii. Visualisation of exudate and membrane on ora and ciliary body. Position of IOL also can be assessed.

Technique Under topical anesthesia, an eye cup is inserted, while the patient is in supine position. A coupling solution is used to fill the cup. A transducer is positioned and the area of interest is scanned. Controlled movement of the eye aids in scanning.‘

EXAMINATION OF LENS

Any disorder of lens will result in some change in vision. It may be associated with involvement of other structures also. Uveitis and glaucoma are examples of such associations. Systemic diseases also may be associated with lental pathology. All these should be kept in mind while examining the lens.

Chief complains Common comblaints are the following:

i. Dimness of vision
ii. Dimness of vision related to intensity of light, e.g. dim vision during day or at evening
iii. Glare
iv. Polyopia—patients usually describe it as seeing multiple bulbs while looking at only one
v. Uniocular diplopia.

Dimness of vision is present in all involvement of lens. An opacity in the visual axis will result in dim vision in bright light as the pupil constricts in bright light. A posterior polar or subcapsular cataract causes such difficulties, whereas a diffuse opacity with result in dim vision in low illumination. Glare is the result of light scattering by the opacities within the lens and is a common problem in lental opacities. Polyopia is seen in early cataracts. Uniocular diplopia is the result of sublaxation of lens resulting in partly phakic and partly aphakic pupil. Lental refractive index may change in sclerosis and in changes of blood sugar levels. The result may be a dimness of vision.

Personal History

Systemic diseases and association are to be noted. Some important systemic causes of cataract formation are diabetes, galactosaemia, hypoparathyroidism, intake of cataractogenic drugs for long period, exposure to infrared and X-rays.

Family History

In some families cataract appear early in life. In congenital cataract maternal history of events during pregnancy is important. Maternal rubella during early pregnancy may cause congenital cataract.

Ocular History

Ocular trauma and surgery, long-standing or recurrent anterior uveitis, retinitis pigmentosa, etc. are some causes or associations of cataract.

SLIT LAMP EXAMINATION OF THE LENS

This is best performed with the pupils dilated to ensure a wide view for the detection of off-axis opacities. A narrow slit beam should be used to minimise patient discomfort and to facilitate the localisation by layer of any opacities as the clinical "slices" through the lens. The examination should start with an angle of 30° between the illumination tower and the microscope objective lenses. The clinician should sweep slowly across the lens. On the first pan, care should be taken to focus on the anterior surface of the lens. On the second pan, the slit beam should be focussed on the posterior surface. Failure to do so causes the clinician to miss subtle posterior subcapsular opacities. Mittendorf's dots, hyaloid remnants and posterior cortical irregularities.

Next, the nucleus should be illuminated and the degree of opacification and colour should be observed. The Y-sutures should be visible as should the zones of discontinuity. Finally, the beam should be moved to concentrate on the cortex for finding out the presence of vacuoles, if any. They have appearance of little air bubbles except that they are refractile, filled with fluid. The clinician can determine the refractive index of the vacuole relative to the surrounding tissue by observing the reflected light. If the reflex from the vacuole is on the same side as the incident beam, the vacuole has a lower refractive index. Conversely, a body with a higher refractive index gives a light reflex on the side opposite to the beam.

The lens should finally be viewed by retro-illumination. The angle between the illumination tower and the microscope should be set at less than 5° such that a bright red fundus reflex is observed. Any opacities appear as dark or translucent shadows against the bright background. A useful method is to focus the slit on the anterior surface of the lens, broaden it slightly, and then rotate it about the 0° position. It is unlikely that more than one half of the pupil area can be retroilluminated at any one time. So the lens must be viewed with illumination from both the nasal and the temporal sides.

Disability glare testing can be done to elucidate symptoms such as difficulty with night driving. The introduction of a glare source into the field of vision can markedly reduce visual acuity, particularly with posterior subcapsular opacities.

When the lens opacity makes it difficult to view the fundus, a range of techniques can be used to assess the viability of the retina and optic nerve, including laser interferometry and the potential acuity meter.

Several lens grading systems are currently available, including the lens opacities classification system (LOCS), the Wilmer system, the Wisconsin system and the Oxford clinical cataract classification and grading systems, typically include standards for nuclear, cortical and posterior subcapsular opacities. LOCS III system established an objective basis for the interval steps used in the grading of different features of cataract. Scaling intervals for grading nuclear opalescence and colour have been chosen to represent equal differences in optical density and colour purity, and the standards for cortical and posterior subcapsular opacities are based on a monotonic function relating the grade to the area of opacification.

Lens Opacities

Age-related lens opacities are divided into three categories nuclear, cortical, and posterior subcapsular.

1. *Nuclear opacities* They are the most common and are often referred to as nuclear sclerosis. The patient experiences a slow, gradual, progressive visual loss. The nucleus begins to take on a milky appearance, owing to increased light scatter, and yellows as a result of absorption of blue light. The change in lens colour is also referred to as brunescence. Due to a concurrent increase in the refractive index of the nucleus, there can be a myopic shift in the refractive error. Finally, localised changes in refractive index may manifest as monocular diplopia.

2. *Cortical opacities* They occur in the cortex of the lens and usually begin outside of the pupil

area and in the inferior nasal quadrant. They may begin as vacuoles, containing fluid, near the anterior adult nucleus. Another early change is the development of water clefts, which appear as radial spokes or cuneiform opacities, pointing towards the centre of the lens. During this process the lens is taking in water and is swelling causing a narrowing of the anterior chamber. At advanced stages when the cortex is completely opaque, the lens returns to its habitual size.

3. *Posterior subcapsular, or cupulliform opacities* They can be considered as a subtype of cortical opacities, though categorised separately owing to their unique location and a greater effect on vision. They develop near the posterior pole of the lens and can appear as a thin layer of vacuoles or crystals. They are best observed by retroillumination appearing as a dark shadow against the bright fundal reflex, unlike the other age-related opacities, posterior subcapsular opacities can occur in younger patients and reduce vision dramatically owing to their proximity to the visual axis and nodal point of the eye. Intuitively, vision should be more affected when pupil size is reduced, such as in bright illumination and during near vision. Posterior subcapsular opacities may also develop seondary to trauma or corticosteroid use.

Congenital and development opacities are commonly observed and usually stable. For example, the Y-sutures may be more pronounced. Epicapsular stars appear as small specks of pigment on the anterior lens capsule.

On the posterior surface, remnants of the hyaloid artery may be visible, either as a white dot (Mittendorf's dot) or as a thread-like attachment on the nasal side of the posterior pole. Vision is rarely compromised.

More serious opacities include those secondary to systemic rubella infection occuring during the first trimester of pregnancy. The opacities may be lamellar or nuclear in nature and can be extremely detrimental to vision. They require early extraction.

Opacification can occur secondary to ocular diseases. Retinitis pigmentosa and Fuch's heterochromic iridocyclitis are both associated with posterior subcapsular opacities. Similarly, systemic disorders particularly of metabolic origin can cause cataract. Juvenile onset diabetes, that is poorly controlled or severe, can lead to snowflake opacities in the anterior and posterior cortex which can progress to complete cortical opacification. Age-related opacities can also occur at a younger age in diabetes. Poorly controlled diabetes can also result in marked changes in refractive error. Hyperglycaemia induces myopic shifts in refractive error, whereas hypoglycaemia shifts refraction in the hypermetropic direction. Even when the patient's blood sugar is regulated appropriately his or her refractive error may take weeks or months to stabilise. Drugs and toxins including phoenthiazines and selenium can lead to lens opacities. The most common iatrogenic cataract is due to either topical or systemic corticosteroid use. Prolonged steroid use typically results in a posterior subcapsular opacity.

Potential Vision Assessment

Potential vision assessment predicts the neural vision behind cataracts or other media opacities and thus the potential vision after cataract surgery.

The most commonly used technique is Maxwellian view projection systems to image a small light source or sources in the eye's entrance pupil. The clinician can control the position of the highly localised Maxwellian beam so that it avoids any cataract or other localised opacity. In this way the estimate of the potential visual acuity should be unaffected by intraocular light scattering.

A single channel Maxwellian view system is used in the potential acuity meter (PAM) to project a letter acuity chart onto the retina. This is, therefore, a highly developed technological improvement over the clinical pinhole test.In this test the patient looks at a Snellen's chart and moves a single or multiple pinholes around in front of his or her eye and tries to obtain the optimal acuity. In this case, the "point source" is at the pinhole in front of the eye rather than in the entrance pupil, the patient attempts to find out a

clear area in the lens and the retinal illuminance of the chart is lower.

Another type of Maxwellian-view system uses two channels to produce an interference fringe on the retina. By increasing the spatial frequency of the interference pattern, a measure of grating acuity can be obtained. The Rodenstock retinometer uses a coherent helium—neon laser to produce an inteference pattern, whereas the Haag-Streit visometer and the IRAS interferometer use two high-frequency square wave gratings at slightly different orientations (moire fringes). The spatial frequency of the inteference patterns is varied by changing the separation distance between two coherent laser beams or changing the orientation of the two high-frequency gratings. The wave fronts from the beams of light produce interference fringes on the retinal surface visible to the patient (Fig. 5.4A, Plate 7). The spatial frequency of the fringes and their orientation may be altered to test the patient's response and visual acuity. Figure 5.4B, Plate 7 shows the appearance of these fringes of dark and bright red light as seen by the patient. The lower half of the picture shows the images in a case of lenticular opacity. Although the image is degraded, the fringe pattern is still visible. It should be noted that as the nonlaser beams pass through the pupil, they are not simple point light sources but imaged diffraction patterns of the objects used. In the case of the PAM, the letter chart image is not a 0.15 mm diameter point source image but a much larger cross-like diffraction pattern.

Other Technique for Qualitative Assessment of Vision

1. Light projection
2. Maddox rod
3. Two light discrimination test
4. Transilluminated Amsler grid
5. Electrophysiological methods (VEP and ERG)
6. B-scan USG
7. Entoptic phenomenon (Blue field entoptoscopy or BFE)

Light projection Normal light projection does not mean that the peripheral retina is healthy but an abnormal light projection definitely points to poor prognosis.

Maddox rod Accurate perception of the orientation of maddox rod suggests normal functioning macula (Fig. 5.5).

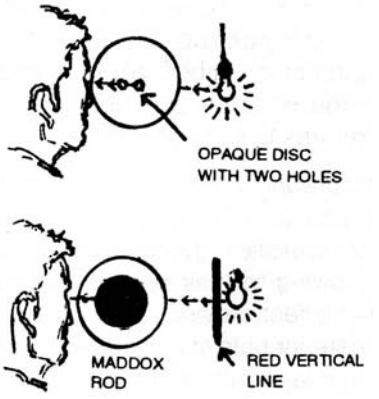


Fig. 5.5: Macular function tests (A) Two light discrimination test (B) Maddox rod test

Two light discrimination If the patient is able to perceive two light sources held 2 inches apart and 2 feet from the eye, suggests normal macula (Fig. 5.5).

Blue field entoptoscopy (BFE) It has the patient describe the presence or absence, number, position and possibly the speed of leukocytes flowing in parafoveal capillaries. Unlike RBC, WBC do not contain hemoglobin, and therefore, are seen in the strong blue light of the instrument.

PREOPERATIVE EVALUATION FOR CATARACT SURGERY

General Examination

Common medical problems in old age like diabetes, hypertension, ischemic heart disease should be under control before surgery.

Diabetes In diabetes patients, fasting and postprandial blood sugar evaluation should be done. Diabetes should be well under control. On the day of operation, antidiabetic treatment should be avoided to prevent hypoglycaemia.

Hypertension Blood pressure should be within normal limits, according to the age group of the patient. If it is not controlled, important investigations like blood urea, serum creatinine and serum cholesterol may be done and physician's opinion should be taken. Cataract surgery can be safely performed with diastolic blood pressure under 100 mmHg. In these patients, phenylephrine and adrenaline should be avoided and pupillary dilatation is achieved with cyclopentolate and tropicamide.

Cardiac Every cardiac patient should have fresh ECG and should follow cardiologist's opinion. Surgery should be done after 6 months of the previous attack of IHD or MI. Here again adrenaline and phenylephrine should be avoided.

Asthma In asthmatic patients, chest auscultation should be done for the presence of rhonchi. Patient should continue the antiasthmatic treatment. We can also give injection deriphylline prior to surgery.

Postoperative strain should be reduced by preventing constipation and urinary retention thus preventing the risk of wound gape and iris prolapse.

Local sepsis should be looked for, i.e. dental caries, tonsillitis, otitis media and diabetic ulcer.

Ocular Examination

Visual acuity Vision should be tested with and without glasses and with pinhole. In advanced and mature cataract, perception and projection of light should be tested in all the four quadrants to rule out gross retinal problems.

Refraction Both eye's refraction should be tested. If extent of cataract does not correspond to the visual loss, posterior segment pathology should be ruled out by special tests. In such case visual prognosis should be explained to the patient to avoid unrealistic expectation regarding vision.

Intraocular pressure Routinely IOP should be tested in both the eyes. In case of any suspicion, glaucoma check-up should be done.

Syringing Patency of nasolacrimal duct should be tested. If the duct is partially free with clear fluid, hourly antibiotic drops should be instilled and conjunctival swab should be taken for culture and sensitivity. The operation should be done only after the culture report comes sterile. If duct is blocked, with mucus or purulent discharge. DCT or DCR and cataract surgery are done after one month.

A-Scan, K-Reading

It is very essential in case of IOL surgery. It gives the power of planoconvex IOL and +2 is added to this for biconvex IOL. In case of scarred cornea and irregular surface of cornea, the K-reading will not be possible. In these cases, the other eye should be taken into consideration.

Slit Lamp Examination

Each and every patient should be examined in detail on slit lamp.

a. Conjunctiva should be looked for superficial and deep congestion. If it is present, swab should be taken for culture and sensitivity and treatment should be started with broad spectrum antibiotics.
   If pterygium is present to a significant extent, it should be excised along with cataract surgery.
b. Cornea should be looked for opacity, degeneration and dystrophy. In case of a central opacity, sphincterotomy should be planned to provide clear visual axis. In corneal dystrophy, scleral or posterior limbal incision should be made and viscoelastics should be used to prevent endothelial cell loss.
c. Anterior chamber should be looked for depth and for the presence of any cells and flare. If anterior chamber is shallow, gonioscopy should be done to rule out angle structure anomalies and angle closure glaucoma.
d. Pupillary reaction should be checked, both direct and consensual. If afferent conduction defect is present it indicates optic nerve dysfunction or gross retinal disorder where the visual prognosis should be explained to the patient. If the pupil is irregular, posterior synechiae should be looked for. At the time of

surgery, sector iridectomy and synechiolysis should be planned with the help of viscoelastics. In case of pseudoexfoliation, adequate pupillary dilatation will not be achieved and also the zonules will be weak, sector iridectomy and gentle surgical manipulation is to be done.

e. Iris should be looked for any iris neovascularisation which indicates underlying chronic retinal hypoxia and neovascularisation particularly in central retinal vein occlusion and porliferative diabetic retinopathy. In these cases profuse bleeding may occur at the time of surgery. It should also be looked for atrophy, synechia and coloboma.
f. Lens should be looked for the type of cataract, maturity and luxation of the lens. In capsular and cortical cataracts, size of nucleus is usually small, so small sized incision is made. In nuclear type of cataract, larger incision should be made. In immature cataracts, capsulotomy is easy to perform but cortical aspiration is slightly difficult but in mature and hypermature cataracts, capsulotomy will be difficult but cortical cleaning will be easier. In case of mild subluxation, IOL surgery is to be performed with very gentle manipulation. If there is gross subluxation and lens dislocation, intracapsular cataract extraction and anterior chamber or primary scleral fixation IOL implantation should be done.

Fundus Examination

Fundus should be examined after full dilatation of pupil by direct ophthalmoscopy. If the media is hazy, indirect ophthalmoscopy should be performed. Certain retinal diseases like diabetic retinopathy, hypertensive retinopathy and age-related macular degeneration are bilateral. In these cases guarded visual prognosis should be explained to patients.

Special tests

A. *Macular function tests* These have the following kinds:

1. Two-point discrimination test
2. Maddox rod test

These tests are done in cases with suspected macular pathology,

B. *USG (B-scan)* It is done in complicated cataract, unilateral mature cataract, traumatic cataract, mature cataract with retinal detachment in the fellow eye, high myopia, intraocular foreign body and when there is inaccurate projection of light. Retinal detachment, vitreous haemorrhage and posterior uveitis can be detected and visual prognosis should be explained.

C. *Gonioscopy* It should be done in glaucoma patients and also in cases where auterior chamber is shallow.

D. *Visual field* It should be examined in glaucoma cases and also in cases with optic nerve disorders.

E. Photostress test and colour perception.

Of these USG is a very important method of evaluation of preoperative intraocular pathologies, like retinal detachment, vitreous haemorrhage, intraocular tumours like malignant melanoma, ciliarly body tumours, etc.

For clinical purpose, if the fundus cannot be seen with direct ophthalmoscope but is visible with indirect ophthalmoscope the opacity is medium. If the fundus cannot be seen with indirect ophthalmoscope the opacity is severe.

Small dot of opacity on the lens may be present after an acute attack of narrow angle glaucoma. It is called Glaukomflecken.

Opacity of lens along with deposit of rust is seen in iron toxicity and greenish yellow spoke like cataract is seen in copper toxicity.

Points to Note

Position of the lens Even after good dilatation of the pupil, the lens covers the pupillary area. The margin of the lens is visible only in the following:

a. Subluxation/dislocation of lens
b. Coloboma of lens
c. Aniridia (absence of iris or only rudimentary iris is present).

In subluxation of lens, the anterior chamber depth is variable at different areas. If the lens is dislocated but still occupies part of the pupillary

area, a bright line of the margin of this lens in visible on an attempt to see the fundus with direct ophthalmoscope. In dislocation into anterior chamber, it looks like a drop of oil and sometimes like blood stained cornea. If the lens is absent from pupillary area whether removed surgically or dislocated into vitreous, the anterior chamber is deep, iris tremulous and the pupil is jet black in colour.

Always note intraocular pressure immediately if you find sublaxation or dislocation of lens.

A few common causes of subluxation/ dislocation are the following:

i. Trauma and couching
ii. Congenital abnormalities like Marfan's syndrome, Weill-Merchesani syndrome, homocystinuria, hyperlysinaemia, Sturge-Weber syndrome, Ehler-Danlos syndrome, etc.

Clarity of the lens The clarity of the lens and its capsule is of prime importance for a clear vision.

The first test should be to perform a careful refraction. The first opportunity to observe the clarity of the media is when observing the retinoscopic reflex. A crisp reflex implies clear media. Nuclear opacities dull and retinoscopic reflex, whereas cortical and posterior subcapsular opacities may appear as dark spokes or dots against an otherwise bright reflex. Subjective refraction is more difficult in patients with lens opacities.

The direct ophthalmoscope is also an useful tool for observing lens opacities with a low plus lens (+6.00 to +8.00 D) dialed into the instrument. The clinician can observe the light reflex from 6 inches (15 cm) with a higher plus lens, say +20.00 D, opacities can be viewed by direct illumination. Finally, the fundus is viewed by direct ophthalmoscopy. The clinician should find out whether his view of the retina agress with the patient's visual acuity.

Pigment on the lens capsule Some has been discussed above in addition to which deposits of iris pigment is seen in iritis. The deposits take time to clear even after iris inflammation has settled. A ring of iris pigment on the interior lens capsule is suggestive of past blunt trauma.

Examination of Artifical Lens

The same examination technique is used to examine the pseudophakos IOL. The anterior chamber lens examination should include gonioscopy to see the position of the foot plate or loop. Do not dilate if an iris supported/iris clip lens is implanted.

An indirect ophthalmoscopy/90-D examination of posterior pole may be useful to detect changes secondary to complications of IOL.

The common complaints for which pseudophakic patients seek advice are the following:

1. Dimness of vision after initial improvement
2. Glare
3. Monocular diplopia/polyopia
4. Unstable vision.

Dimness of vision after initial improvement may be due to posterior capsular opacity, late uveitis or glaucoma.

Glare may be due to posterior capsular opacity and lens decentration.

Monoocular diplopia/polyopia, and unstable vision is always related to lens decentration.

The term lens (IOL) decentration means a position of IOL when edge of the lens of positioning hole is seen through a mid dilated pupil (about 5 mm).

When an IOL occupies only a small fraction of pupillary area it is considered subluxated and when the IOL is in the posterior segment, in vitreous or on retina it is called dislocated.

Sunset of sunrise syndrome When the lens is decentered/subluxated inferiorly, it is termed the Sunset syndrome and if it is subluxated superiorly, it is termed the Sunrise syndrome.

Chapter 6

Examination of Glaucoma

HISTORY TAKING

During history taking in glaucoma patients, following points must be thoroughly investigated:

Emotional Status of the Patient

Primary narrow angle glaucoma (PNAG) occurs more in persons who are highly anxious and sympatheticotonic in nature. Primary open angle glaucoma (POAG) occurs four times more frequently in females than in males.

Any General Disease of the Patient

Special attention must be given to a history of the following:

Systemic hypertension Sudden lowering of an elevated systemic blood pressure, in patients with established glaucoma, may precipitate acute field loss in susceptible persons.

Diabetes mellitus High prevalence in POAG and the IOP of both adult and juvenile diabetic patients appear to be higher than in nondiabetic patients. In addition, secondary glaucomas can develop as a direct or indirect consequence of diabetes mellitus.

Any episode of electrical shock Transient elevation of IOP have been observed after electrical injury, cardioversion and electroshock therapy due to venous dilatation, pigment dispersion, etc.

Respiratory disease including a history of asthma Topical beta-adrenergic antagonists reduce forced expiratory volume and forced vital capacity in patients with asthma.

Cardiovascular disease Local ocular ischaemia including central retinal vein occlusion and rare central retinal artery occlusion can lead to development of rubeosis iridis and haemorrhagic glaucoma.

Cerebrovascular disease Elevated episcleral venous pressure and secondary glaucoma may arise from arteriovenous malformations or from carotido-cavernous fistulas.

Renal disease including kidney stones Elevated IOP occurs in patients after renal transplantation. In cystinosis with renal involvement IOP may rise.

Thyroid disease Some investigators relate this to POAG. Secondary glaucoma can occur in thyrotropic ophthalmopathy.

POAG occurs in subjects of vascular sclerosis treatment.

Past history of epidemic dropsy.

Ocular History

Any previous disease, treatment or injury to the eyeball.

The ocular history alongwith prior ophthalmic records if available is necessary in providing clues to the diagnosis of the glaucoma. The following factors must be enquired:

1. History of ocular trauma.
2. Prior ocular surgery.
3. Symptoms relating to acute elevations in intraocular pressure.
4. History or symptoms relating to uveitis.
5. History of prolonged administration of topical or systemic corticosteroids.

First Symptoms Noticed

i. Age of onset

PNAG affects about 0.1 per cent people above the age of 40 years and forms nearly 10 per cent of all glaucomas.

POAG affects about 0.4 per cent people above the age of 40 years. PNAG with pupillary block occurs with greatest frequency in the 6th and 7th

decades of life. Though it can occur in any age including childhood.

Prevalence of POAG increases with age.

ii. Change of glasses

Some patients with POAG often complain of difficulty in close work owing to a reduction in the power of accommodation (due to pressure atrophy of the ciliary muscle).

iii. Any acute attack? Unilateral/bilateral pain? Headache? Vomiting? Blurring/ haloes? Scotomas?

Attack of blurring/haloes/scotomas: Occasionally patients of POAG notice scotoma while doing monocular work or the young patient who has sudden, severe elevations in intraocular pressure that cause corneal oedema encounters halo vision and discomfort.

Acute attack of PNAG with pupillary block alongwith pain along trigeminal distribution (eye, orbit, head, ear, sinuses or teeth) and accompanying nausea, vomiting, sweating and bradycardia may occur. High intraocular pressure blurs vision—at first it stretches the corneal lamellae and later because it produces corneal oedema. Corneal oedema acts as a diffraction grating which breaks white light into component colours causing patients to note coloured haloes or rainbows around incandescent lights, with blue green colours in the central and yellow red colours in the peripheral part (Fincham's test, Fig. 6.1). They are usually unilateral. Patient may have similar attacks in the past.

iv. Any precipitant?

PNAG: Many cases are precipitated by moderate dilatation of the pupil (3.0 to 4.5 mm).

Emotional upset: Bad news, pain, fear, illness or accident and dim illumination (e.g. in a restaurant or cinema, etc.) increase sympathetic tone to dilator muscles.

Medications (topically/systemically/transdermally): It includes tranquilisers, bronchodilators, vasoconstrictors, appetite suppressants, antiparkinsonian agents, cold preparations and antispasmodics (these drugs dilate the pupil through an anticholinergic effect on sphincter muscle or a sympathomimetic effect on dilator muscle).

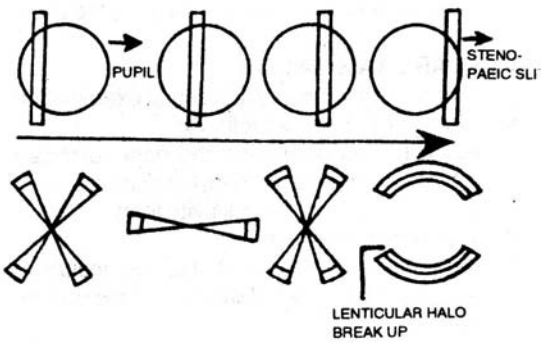


Fig. 6.1: Fincham's test: A stenopaeic slit is passed before the eye across the line of vision. Glaucomatous halo: Remains intact but diminishes in intensity. Lenticular halo: Broken up into segments which resolves as the slit is moved. Typically seen in incipient cataract due to prismatic effect of the wedge-shaped peripheral cortical opacities

Family history POAG is usually inherited (A-D, A-R, sex-linked) in a multifactorial manner with variable penetrance. It is familial and nearly 10 per cent of first degree relatives (parents, siblings and offsprings) of glaucomatous patients eventually develop the disease.

Though PNAG is usually sporadic, some pedigrees with autosomal dominant and some with autosomal recessive traits are reported.

Type of refractive errors PNAG is much higher in hyperopic eyes with shallow AC. POAG is common in myopes.

Present treatment If the patient is already under treatment, attempts should be made to obtain past medical records including previous visual field charts and optic disc photographs. The ocular history of a glaucoma patient should be taken for each eye and include the following:

a. Type of glaucoma diagnosed
b. Date of glaucoma diagnosis
c. Highest recorded intraocular pressure.
d. Prior and current glaucoma medical therapy with specific dates.
e. Any history of adverse reactions to prior glaucoma agents with a detailed description of the side effects which require stopping of medication.

f. Dates and types of prior intraocular and laser surgery including records indicating the sites.

OCULAR EXAMINATION

After obtaining the history, the ocular examination should be performed as follows:

1. Refraction to determine the best corrected visual acuity and recording of visual acuity on each visit (contrast sensitivity test).
2. Visual field examinations.
3. External examination of the eye including testing for an afferent (Marcus-Gunn) pupillary defect.

The anterior segment must be examined by slit lamp biomicroscopy. Particular attention must be given to signs of secondary glaucoma.

i. Examination of lid and conjunctiva: Episcleral congestion may be due to elevated episcleral venous pressure.

In acute congestive glaucoma (ACG) ciliary flush due to injection of the limbal and conjunctival blood vessels.

ii. Examination of cornea: In intermittent OAG the corneal epithelium is oedematous and in acute congestive type there will be corneal oedema, with epithelial vesicles. Krukenberg's spindle, keratic precipitates and Fuch's dystrophy must be looked for. In buphthalmos, breaks in Descemet's membrane may occur.

Corneal diameter must be measured as it is related to depth of anterior chamber and width of the angle. Eyes with PACG have corneal diameter 0.25 mm smaller than normal eyes. In buphthalmos the corneal diameter is much longer (more then 12 mm).

iii. Anterior chamber: In PACG, Anterior chamber is shallow with iridocorneal contact which can be best detected by directing a narrow slit beam to the limbus at an angle of about 60°. Aqueous flair and cells are also present in acute congestive phase.

iv. Iris and pupil: In intermittent angle closure glaucoma, the pupil may be semidilated and in acute congestive phase it is vertically oval and fixed in semidilated position and unreactive to both light and accommodation. Dilated and congested blood vessels on the iris are visible in acute congestive phase (if the cornea is clear). Afferent pupillary conduction defect, pigment granules, posterior synechiae, atrophy and rubeosis must be excluded. In PACG, the iris–lens diaphragm is convex shaped and there is close proximity of the iris to the cornea.

v. Lens: Opacities, glaukomflecken, pseudoexfoliation, phacodonesis must be looked for.

4. Slit lamp examination with special attention to:
   i. Central and peripheral chamber depths.
   ii. Comparison of chamber depths between the two eyes.
   iii. Signs of pigmentary dispersion syndrome.
   iv. Iris sphincter atrophy which may be a sign of the exfoliation syndrome.
   v. Iridodonesis and phacodonesis.
   vi. Presence of lenticular changes.
   vii. Signs of uveitis including cellular reaction and posterior synechia.
   viii. Rubeosis iridis.
5. Measurement of intraocular pressure (discussed later on).
6. Gonioscopy (discussed later on).
7. If the iridocorneal angle is open and nonoccludable following examinations are performed:
   A. Dilated fundus examination for direct examination of the posterior pole and indirect peripheral ophthalmoscopy.
   B. Stereo-optic disc photography.
   C. Dilated slit lamp examination noting the following:
      i. Presence of pseudoexfoliation.
      ii. Presence of pigment deposits on the equator and posterior aspects of the lens, appearance of the anterior vitreous.
      iii. Optic disc examination with a contact lens, the Hruby lens or the 90 diopter lens.

iv. Description of the optic disc: Contour and colour, cup-to-disc ratio, disc haemorrhages, notching, etc.

8. If the iridocorneal angle is narrow and possibly occludable:
   i. Pupil dilatation, if done, must be performed carefully using an easily reversible agent and dilating one eye at a time. The patient must be informed of a possible provocative acute attack. In some patients pupil should not be dilated until a laser iridotomy has been performed.
   ii. Stereo-optic disc photography and slit lamp examination are performed on the dilated eye.

Optic Disc Changes in Glaucoma

Optic disc cupping: The cupping may begin as a symmetric enlargement of the physiologic cup but usually some portions of the rim erode more rapidly than the rest. Usually the inferior temporal or less commonly, the superior temporal rim becomes thinner. Occasionally this thinning is localised and seen as a notch or less frequently a pit at the disc rim. When notches are present both superiorly and inferiorly, the cup becomes vertically oval, the slope of the disc cup is usually steepest nasally and becomes shallowest temporally, with the upper pole having a somewhat steeper slope than the lower pole (Fig. 6.2).

As the cup enlarges, the retinal vessels, which usually pass perpendicularly through the disc tissue to reach the retina, are pushed aside following the receding nasal wall of the cup. Whereever the vessels shift from a more vertical orientation along the cup wall to a horizontal orientation on the retinal surface, there is a bend in the vessel. Changes in the shape and position of the bend is a sensitive indicator of disc changes.

Vessels that pass circumferentially across the temporal aspect of the cup are called circumlinear vessels. If they pass through the exposed depths of the cup, they are "bared". Baring of the circumlinear vessels is seen because as the cup recedes it exposes the vessels. It is seen commonly in glaucomatous cups but may be seen in normal cups as well.

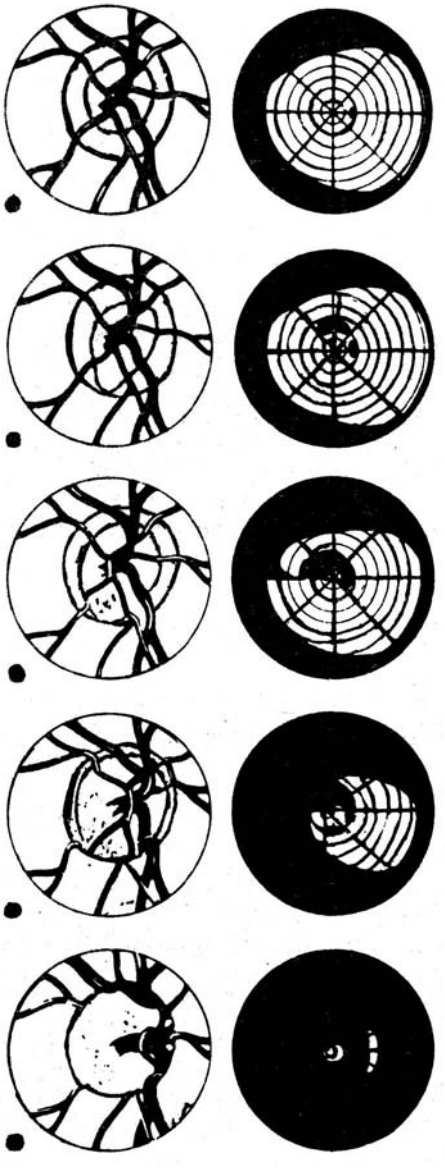


Fig. 6.2: Optic disc cupping

Colour As the cup enlarges, its colour often changes from pink to white in the terminal stages. Cupping occurs slowly unless the pressure is very high.

Reversal of cupping can be dramatic in young patients following surgical or medical lowering of intraocular pressure. Reversal is less dramatic in

older patients, presumably because of reduced elasticity of the scleral tissue in older patients, which does not allow the cup to resume its prior configuration. Moreover, the cupping resulting from actual loss of nerve tissue is unlikely to reverse.

TECHNIQUES OF OPTIC NERVE AND NERVE FIBRE LAYER EVALUATION

1. Clinical examination of stereoscopic colour optic nerve photographs.
2. Monochromatic high-contrast photographs of the nerve fibre layer.
3. Digital image analysis of the optic nerve head (ONH) structures.
4. Digital image analysis of the nerve fibre layer height.
5. Manual planimetric measurements of the disc rim.

Stereoscopic Optic Disc Photography

Progressive cupping of the optic nerve head (ONH) is one of the most reliable indicators of progression of the disease process and inadequate glaucoma control. Therefore, the subtle changes in the appearance of the optic disc need to be accurately recorded during the course of follow-up examinations. Periodic photography of ONH and stereoscopic photography, if available, will provide a reproducible image and base line for future comparison. This may be accomplished using either sequential or simulataneous photographic techniques. Among these two techniques, the most widely available and utilised modality involves obtaining two consecutive images of the optic nerve using a manual shift of the joystick. The Zeiss fundus camera traditionally has been the standard for obtaining stereoscopic image in a sequential fashion. Alternatively, both images may be captured with a single exposure using a simultaneous stereoscopic fundus camera such as those manufactured by Nidex technologies and Topcon Instrument Corporation. For maintaining longitudinal follow-up with one uniform fundus camera per patient is recommended. Both the Nidex and Topcon fundus cameras provide optional digital analysis systems to analyse the ONH topography and RNFL.

Sequential (Consecutive) Stereoscopic Optic Disc Photography

Allen's stereo-separator It is a technique that captures stereoscopic images in a consecutive fashion. This technique is often performed using a manual shift of the camera joystick to obtain stereo-images through opposite sides of the pupil. Alternatively, an adjunctive device called Allen stereo-separator may be employed to create stereo-disc images.

Lee Allen, in 1964, developed a special adaptor that was designed to fit upon the back of a fundus camera which was equipped with a 2 x magnification accessory in place. This would result in 5 x print magnification. The unit contained a sliding carriage that would house a 4 x 5 inch film packet and a built-in switch that would synchronise the electronic flash with the Packard-type shutter. Stereoscopic photography was accomplished by sliding the adapter to the right for making the picture to be viewed with the left eye. After taking the exposure, the sliding carriage would be moved to the left for the picture to be viewed with the right eye. The stereo-separator currently consists of a motorised device that fits Zeiss fundus camera. Driven by the camera's power transformer, the unit contains a swiveling glass plate that is suspended over the front camera lens. The alignment of the glass plate primarily is checked manually to ensure adequate exposures. Stereo-separation of images (Stereo-base) is created by optically directing light towards alternate aspects of the dilated pupil. The degree of the arc through which the glass plate swivels may be controlled to standardise the stereo-base. Alternate exposures may be obtained in rapid sequence using a motorised foot switch to control the shutter release. A notable drawback of this technique is the 6 mm pupil diameter required to achieve stereo-image. This level of pupillary dilatation may be difficult to achieve in eyes on chronic miotic therapy.

Manual shift technique This technique may be performed with any fundus camera though it is

typically accomplished using a standard Zeiss fundus camera (Zeis' FF-4).

The Zeiss FF 4 camera creates stereoscopic images using a sequential technique. Full-frame images are created with a photographic magnification of 2.5 x. The viewing magnification is 16x and the minimum pupil diameter is 3 mm. The camera is equipped for fluorescein angiography with excitation and barrier filters. A green filter is available for performing RNFL (red free) photography.

Stereo-images obtained with this technique are generally of very high stereo-quality though they are least reproducible. This is also least expensive.

This technique simply involves manually moving the camera joystick control to the 9 O'clock position of the pupil and capturing the left frame of the stereo-pair. The right frame of the stereo-pair is then obtained by moving the joystick across the visual axis to the 3 O'clock position of the pupil. One should obtain maximum pupillary dilatation with topical mydriatics. This may be difficult for patient on chronic miotic therapy. If possible, it may be helpful to have the patient discontinue miotic therapy approximately 24 hours prior to the expected photographic sessions. A uniform stereo-base needs a uniform degree of pupillary dilatation.

Now, focus on the optic disc in the centre of the pupil to obtain a photographic image. Do not forget to have the patient blink before obtaining each image to lubricate the ocular surface and improve the image quality. Move the joystick to the left until a yellow crescent artifact appears. Continue to move the joystick towards the left unitl the artifact disappears. One may need to move the camera body away from the patient if crescent persists. The image will appear noticeably darker since a portion of the light entering the eye is obstructed by the edge of the pupil. Obtain an image of the optic disc which will serve as the right frame of the stereo-pair. Move the joystick slightly towards the right across the patient's visual axis. It must be emphasised that the camera axis must remain parallel between images in order to create the stereo-base. As outlined above, obtain an image of the optic disc at this side of the dilated pupil after manipulating the joystick to reduce the yellow artifact. This will severe as left frame of the stereo-pair.

For purpose of stereoviewing, one should always pair the central image with either the left or right image. One would assume that in order to get the best stereo-base, one should pair the left image with the right image. As these images are typically the darkest and less clear, the clinician should avoid pairing them during assessments of the optic disc. To enhance visualisation an auxilliary 2x objective sleeve may be used to provide greater photographic magnification.

Simultaneous Stereoscopic Optic Disc Photography

Twin Prism method It is a device to capture instantaneous stereo-images with a single exposure and it was constructed to fit over the objective lens of a standard Zeis' fundus camera. It consists of a pair of 7 diopter prisms mounted apex to apex with a tilt of 15° in the vertical plane. When compared to Allen's stereo-separator (sequential stereoscopic photography) the required minimum pupillary diameter was 2 mm larger with this method (8 mm) and it provides significantly greater reproducibility than the method using Allen's separator. Patients on chronic miotic therapy would not be acceptable for study in this method. In addition, significant prism-induced distortion is introduced using this method thus making its use difficult in most clinical settings.

Donaldson's fundus camera The optical principles of the camera are based upon those of binocular indirect ophthalmoscopy. The pupillary space is divided vertically so that the illuminating light rays entering the eye are separated from the emerging ray of light leaving the pupil. The optical system involves capturing images from two distinct vantage points through the 3 and 9 O'clock positions of the pupil. The stereo-base depends directly upon the separation of two aperture placed in front of a pair of rhomboid prisms. Light rays

from the fundus subsequently pass through a pair of camera lenses and are focussed at the film plane, after the double reflex mirror system is shifted into a horizontal position.

The stereo-base may be varied with the use of interchangeable aperture plates placed in front of the rhomboid prisms. Loss of detail and poor image resolution may result if the separation of the apertures is too great and the stereoscopic effect will be minimised if the separation is too small. The optimum separation is 5 mm. The minimum pupil diameter recommended to obtain satisfactory images is 4 mm. Photographic magnification is 6 x. A 30° picture angle of the fundus is captured. This camera is not commercially available.

Nidex 3 D camera It captures simultaneous stereoscopic images with a 32° view of the fundus. There is a binocular eyepiece with an adjustable pupillary distance. Most clinicians document the optic nerve image using a split-frame image with two adjacent stereoscopic images of the optic nerve that appear on a 35 mm slide. These images are reviewed stereoscopically with a specialised viewing system such as the stereo-viewer II (Asahi Pentax Co). Alternatively, the images may be obtained in the form of a polaroid, or as a 3.5" x 5" three dimensional transparency. No specialised viewing system is needed for the latter. Photographic magnification is 2.6x with a viewing magnification of 24.1x. A minimum pupil diameter of 4 mm is recommended to obtain good stereoscopic images with a stereo-base of 3 mm, NFL photography may be performed, as this unit is equipped with internal green (red-free) and blue filters. FFA may be performed as it contains excitation and barrier filters. This instrument has the capacity to digitally display and evaluate the ONH topography, to analyse the RNFL, and to detect positional shift in the major retinal vascular arcades. A digitised wire basket plot can be generated. Using a custom-designed reticule, horizontal and vertical cup and disc diameters can be measured.

Topcon TRC-SS2 camera It produces simultaneous stereoscopic images in form of split-frame image. If compared to Nidex fundus camera, both of them produce high quality images with a photographic magnification of 2.6 x and both are equipped to perform RNFL photography. Topcon unit captures a 30° picture angle of the fundus through a monocular eyepiece. The viewing magnification is 16.5x. The minimum pupil diameter recommended to obtain satisfactory images is 5.5. mm.

It can produce accurate high-resolution, reproducible simultaneous stereoscopic images of the ONH. This unit is directly capable of producing FFA. An optional digital ONH analysis system (imagenet stereo-analysis system) is also available. This system is capable of producing digital analysis of the ONH topography including cup-to-disc ratio, pallor to disc ratio, cup volume, and disc peripheral length areas. Overlay sections can be compared using an optic disc change analysis programme. Contour wire basket plots, color-coded depth maps, numerical depth maps, and cross-sectional analysis can be performed as well as measurements of the RNFL and analysis of retinal vascular shift. Stereometric analyses and wire basket plots may be generated in about 4 to 5 minutes.

Glaucoma-scope Glaucoma-scope is a computerised ONH analyser that is based on a technique of computer raster stereography. A series of equidistant, parallel, straight lines is projected onto the optic disc at an oblique angle. Based on the deflections of the lines, the depth and volume can be calculated. The deflection of the projected lines is proportional to the extent of papillary excavation—small deflections indicate shallow depth, whereas large deflections occur with deep cup excavation.

Method

The glaucoma-scope has two components—the optical head mounted on a joystick for image acquisition and a computer for image analysis. A halogen lamp illumination system within the optical head projects a series of about 25 horizontal lines across the ONH. The light lines are projected at an angle of 9° to the ONH using near infrared light

(750 nm). A polarising filter is used to maximise reflection from the anterior surface of the NFL. A video-image of the ONH and the projected lines are viewed on the monitor, and image quality is optimised by operator control of focus and illumination. Multiple images are captured by pressing a button near the joystick. The captured images are stored in digital form on optical discs.

Quality scale The quality of the images is ranked on a logarithmic scale ranging from zero to infinity. The scale is proportional to the ratio of horizontal line data to non-horizontal line data of the image. The quality scale to zero for images that are too bright for analysis. A quality scale of zero indicates that no horizontal lines are present whereas an image of mostly horizontal lines would produce a large number. Images with quality scale less than 4 generate an error message that can be overridden to attempt topographic analysis of the image. Images with quality scale more than 4 are adequate for image analysis. Images with adequate quality have even illumination and sufficient line contrast. A quality scale of approximately 10 is considered a very good image for analysis, and a scale more than 15 is an excellent image for analysis.

A reference point is selected for future image registration, which devotes the centre of a 128 by 128 pixel reference area. In subsequent examinations, the previously selected reference point appear in a window in the corner of the image. The operator selects a point on the current image that is near the reference point to allow the alignment of the initial and subsequent images.

The alignment is the best fit of the 128 by 128 pixel area around the reference point in the intial image compared with the subsequent image. The selected points on the current image must be within the theoretical limit of 64 pixels from the original reference point, but the actual required proximity of these points is determined by the quality of the images. Ideally, the selected points should be within 5 to 10 pixels from the original reference point. At the first visit the operator identifies the disc margin by placing minimum eight points around the disc margin and outlines the major vessels. The disc margin and vessel drawings provide landmarks on reports but do not affect algorithm calculation of depth values. After analysis of the line data, the line information is displayed with the video image of the disc. An algorithm converts the captured horizontal line data from the captured image into corresponding topographic depth values. The reference plane for depth measurements is defined by linear interpolation of data within two 50-micron columns placed 0.3 disc diameters nasal and temporal to the disc margin.

The optic cup area is defined as the area inside the disc margin—140 microns or more below the reference plane. The refraction of the eye is required to allow calculation of the real size of the disc and cup.

The data are reported as a numeric and gray scale printout up to 722 numeric depth values appear on the printout in a 19 by 38 number grid, with each value representing about 136 data points covering an area of 69 microns vertically by 138 microns horizontally. If no line data exist in an area, the depth values are not extrapolated, and a "X" appears on the printout. On subsequent visits, the depth measurements are automatically compared with measurements made at the first visit, and a change-from-baseline analysis is printed showing any changes in the depth values of more than 75 microns.

Pupil The minimum pupil size needed is 4 mm though image can be captured in smaller pupils with clear media.

[Typical image acquisition needs 1 to 5 minutes. The current algorithm and microprocessors perform the image analysis in 1 minute. Report printing needs about 4 minutes].

Report interpretation

Reports contain depth information as depth numbers (microns) on as a gray scale and colour topography maps, profile sections and common disc parameters.

The numeric depth information is presented on a 19 x 38 number grid. Areas where no line data exist are indicated with an "X" on the printout. Numbers defined as low confidence appear as

lighter numbers. These low confidence numbers are those numbers with discontinuities in the horizontal line data. These are generally in areas of edges or steep slopes, where horizontal line data are absent. Numbers printed in bold types are high confidence numbers indicating areas with reliable horizontal line data. The gray scale analysis indicates increasing depth with progressively darker shades of gray, allowing rapid visual assessment. In the change-from-baseline analysis, values that have changed by more than 75 microns are shown. These changes may be due to real changes in the topography of the disc or lack of reproducibility. Areas of non-reproducible change may be due to fluctuations of the algorithm, or changes due to steep slopes and pulsations around blood vessles. These areas of artifacts may be readily identified by comparing several images captured on the same day to the baseline images. Areas of real change are reproducible in comparisons of several images from the same day to the baseline images (Fig. 6.3).

Colour topography maps include a three-dimensional map and a two dimensional disc and cup outline. The three-dimensional map is colour coded, with shades of blue representing shallow depths, green and yellow indicating intermediate depths and shades of red showing deeper areas of the cup. The cup outline shows all depth areas more than 140 microns in red, and shallower areas within the disc margin in yellow (Fig. 6.4, Plate 8).

Profile sections show the cross-sectional depth at the maximum horizontal and vertical cup diameters. In these profiles, the disc margins are shown in bold vertical lines. The depth of the current analysis is represented by a solid red line and the baseline analysis is indicated by a dashed blue line.

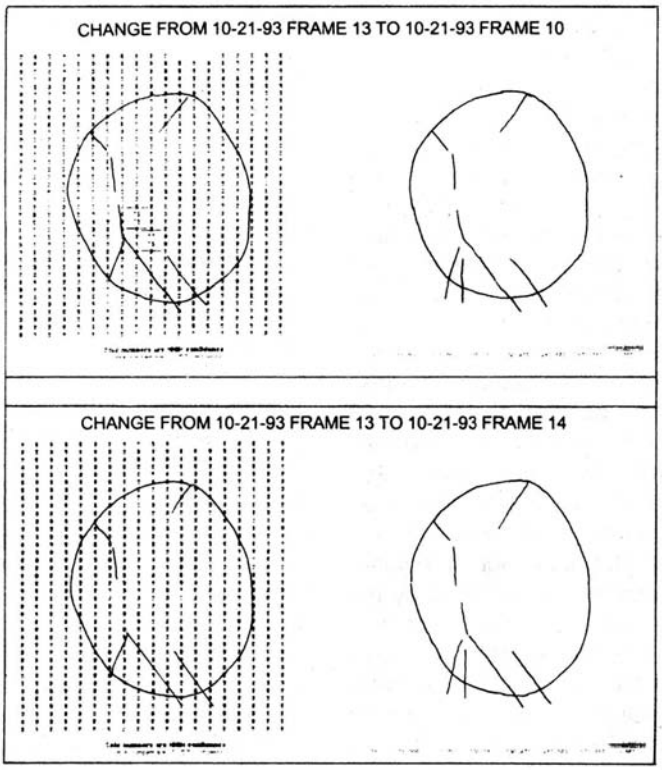


Fig. 6.3: Glaucoma-scope report: Change-from-baseline analysis

A "nerve fibre analysis" shows the measurement of the retinal height compared with the reference plane. Areas of peak heights on this analysis usually represent blood vessels of thicker areas of NFL. The retinal height is shown 200 microns away from the disc margin circumferential to the disc, including temporal (T), superior (S), nasal (N) and inferior (I) areas.

Common parameters are displayed for the current and baseline analysis. The cup-to-disc ratio (horizontal and vertical) and the cup-to-disc area ratio are shown. The cup is defined as the area within the disc margin that is at least 140 microns deep. Also displayed are the maximum disc diameter (horizontal and vertical), the disc area, the cup area, as well as the refraction of the eye. The "MP disc" is the mean value of the depth numbers inside the disc edge and the "MP total region" is the mean depth of all points measured in the analysis, including points inside and outside the disc.

Limitations

The conditions associated with inability to obtain a satisfactory image are hyperpigmented fundi, pseudophakia, aphakia, corneal opacities, cataract and contact lenses. Optic disc hemorrhages may not be detected by glaucoma-scope or other ONH analysers and are most effectively documented by conventional optic nerve photographs.

Glaucoma-scope is useful in detecting the acute and chronic changes that may represent transient or permanent changes in ONH topography. The initial examination analysis effectively determines the optic nerve topography. The gray scale report provides a rapid view of the extent of optic nerve cupping. In comparing both eyes asymmetric optic nerve cupping may be documented. Subtle asymmetry of the optic nerve contour may be detected. Disc elevation may also be demonstrated, indicated by positive numbers in the glaucoma-scope depth analysis. Areas of decreased retinal height in the peripapillary area may be demonstrated, which may correspond with abnormalities of the ONH. Follow-up examinations can determine the progresive changes. In ocular hypertensive patients, disc changes may be documented without visual field changes. Finding reproducible changes in ONH contour may be helpful in the management of low tenstions glaucoma. On follow-up examinations, repeatable changes of depth measurements suggest changes of contour of the ONH.

Confocal Scanning Laser Topography (CSLT)/ Tomography/Ophthalmoscopy (CSLO)

Confocal Scanning Laser Tomography has been used in the evaluation of the ONH in glaucoma. The Heidelberg Retina Tomograph and the Topographic Scanning System (Top SS) the two commercialy available systems in use are easy to perform and patient friendly compared to automated perimetry. A topographic image of the optic nerve containing more than 2 million data points is obtained in less than 1 second.

Principle

The illumination in the system is a diode laser (670 nm wavelangth) with confocal optics. The confocal system contains a pinhole located in the plane conjugate to the focal plane of the laser, which in turn, is located just in front of the detector. The pinhole ensures that only light originating from the focal plane of the laser is registered, the rest being eliminated. Cross-sectional images of the structure can be obtained by varying the focal plane of the laser. The confocal images are aligned for horizontal and vertical shift arising out of small eye movements. Reflectivity is measured on a relative percentage scale while topography is measured in microns from the focal plane of the eye. Typically, during imaging, about three images per eye are acquired. Once multiple topography images have been obtained, they are aligned for any shifts between the images and a mean value is obtained.

The laser beam enters the eye through the pupil; a 10 micron spot is focussed on the retina. The spot size determines the lateral resolution of the scanning laser ophthalmoscope. The light reflected from this illuminated area is detected by this highly sensitive photo detector, then digitised and displayed on a video monitor as one picture element or pixel. The laser beam then scans

laterally to the next point to illuminate, the adjacent area. This procedure is repeated until a line comprising 256 pixels is scanned. After completing a line the laser beam returns to the beginning of the line and is moved a step down by a vertical detection unit to start the next line. This faster scanning is repeated until a complete image has been generated.

The cup in its three-dimensional computerised projection can be examined from various perspectives to yield a graphic outline of the height and depressions of the disc. A colour computerised printout can also be obtained both on instrument screen and in hard copy on paper for a chart. From the computer generated image a three-dimensional wire diagram of the disc can also be created.

The Heidelberg Retina Tomograph (HRT) acquires 32 equally spaced confocal images along the Z-axis (perpendicular to the optical axis). The image resolution is 256 x 256 picture elements (pixels), resulting in 65,536 measurements per image. The total scan depth can be raised from 0.50 to 4.00 mm, while the scan area can be set to 10 x 10 degrees. The total image acquisition time is 1.6 seconds. The 32 images are aligned for horizontal and vertical shifts that may result from small eye movements during image acquisition. The sum of the reflectance measurements along the Z-axis for each aligned pixel is used to generate a reflectivity image, while the location along the Z-axis, where the maximum reflectance is registered, is assumed to be the height of the location and used to generate a topography image. Reflectivity is measured on a relative percentage scale, while topography is measured in micrometers from the focal plane of the eye.

Clinical applications

1. *Determination of ONH parameters* Once topographic images have been obtained, they can be analysed. The parameters which can be calculated from them are: optic nerve head area, neuroretinal rim area and optic cup volume. The neuroretinal rim volume and cup-shape index can also be determined. The optic nerve head area can be calculated by manually drawing the border of the ONH with the help of a computer mouse. Based on the height values of the contour line, a reference plane is determined. The papillomacular bundle is often chosen as a reference plane, as it is the last structure to be affected in glaucoma (Fig. 6.5, Plate 8).
2. *Determination of progression* This is done by comparing the ONH parameters, such as the neuroretinal rim area, or cup volume with previous baseline data.

With the HRT, the standard reference is defined as a plane 50 microns posterior to the mean height of the peripapillary retinal height along the contour line at a temporal segment between 350° and 356° below the horizontal line. Cup area, cupdisc area ratio, cup volume, rim area, rim volume, RNFL thickness, and RNFL cross-section are calculated relative to the reference plane.

The curved surface is not a plane. It has the height along the corrected contour line as its boundary. The centre of the curved surface is the mean height of the peripapillary retinal surface along the corrected contour line. Each section of the curved surface from its centre to its boundary point is a straight line. Topographic optic disc parameter like cup volume below the surface, mean cup depth, maximum cup depth, and cup shape are measured relative to the curved surface (Fig. 6.6, Plate 9).

Two quantitative methods are used for the longitudinal analysis of the topographic information.

1. Evaluation of topographic difference images: Topographic difference images are determined from the mean topography images of two examinations after automatic correction for shift, rotation and tilt between the images. Based on multiple image acquisition during each visit, the software also determines the reproducibility for each individual examination. This allows the significance of a detected local height change to be calculated and displayed in false colour codes. Areas in red

are significantly deeper in the follow-up examination than in the baseline examination. Areas where the surface is significantly higher are displayed as green. The sensitivity for detecting changes is influenced by the reproducibility of the height measurements. The mean reproducibility for the 256 by 256 height measurement with the latest HRT software has been reduced by about 30 per cent and is often less than 25 microns in a glaucoma patient.

2. Evaluation of changes of stereometric parameters.

CLINICAL EXAMINATION OF THE NERVE FIBRE LAYER (NFL)

The axon bundles reflect light and therefore become visible as silvery striations with the proper viewing technique. Green and blue light reflects from the NFL better than other colour lights. The green or blue wavelengths are more highly absorbed by the retinal pigment epithelium and choroid, and therefore, the reflected light allows more contrast and easier viewing of the NFL. In patients with more pigmented retinal pigment epithelium and choroid, the NFL is more easily viewed due to this contrast effect.

In patients with glaucoma NFL abnormalities has been noticed. The NFL atrophy has also been found to correlate with the decrease of the neuroretinal rim area of the optic disc also with statistical indices on automated perimetry. Focal NFL defects have correlated with focal visual field defects as well. NFL atrophy has been shown to progress after optic disc hemorrhage.

Techniques for Viewing the NFL

The NFL is best visualised using a red-free or green light. A good stereoscopic image of the NFL is desired. The optimal lens is probably a Goldmann or other contact fundus lens. The 78 D indirect non-contact fundus lens also allows an excellent magnification and stereoscopic view of the NFL. A 90 D lens also allows a larger field of view with less magnification, or a Hruby lens. Some prefer a direct ophthalmoscope with the red-free light for high power examination of the NFL without stereoscopic image. This is particularly helpful in cases with miotic pupils. Using any of the lenses, the red-free light should be oriented as a wide, short slit beam, and a systematic examination of the NFL can then be performed.

NFL photography Examination should begin with the striations. The brightest striations should be most prominent in the superior and inferior poles, and should transition to less bright striations as the viewer examines the papillomacular bundle. The superior to the inferior striations should be compared and also the fellow eyes, for any abrupt gaps or any diffuse differences.

The striations should have a characteristic texture, described as rice grains laid end to end. This texture should be visible at the superior and inferior poles, and will be noticeable as the striations cross over the retinal blood vessels. A decrease in the visibility of the texture may indicate thinning of the NFL. The medium sized retinal blood vessels are normally covered by a thin layer of nerve fibres as they course to the disc causing the blood vessels to appear slightly blurred at the margins. With NFL thinning these medium sized blood vessels appear sharper and more distinct.

NFL visualisation may be difficult in media opacity (e.g. cataract), poorly focussed photographs, lightly pigmented fundus (due to poor contrast), glare from a cataract or slit lamp beam that is too bright or wide in advanced cases of glaucoma, the NFL may be so thin as to be undetectable.

Patterns of NFL loss in glaucoma NFL loss may be diffused or localised. Localised loss, although easier to detect, is rare than diffused loss. Diffused loss can be detected by comparing the superior and inferior regions in one eye and also with the other eye. The examiner will find loss of striations, less texture, and more prominent appearing medium sized vessels in an entire zone.

Localised, or wedge defects are more striking and more easily recognised. The defect will have

an arcuate course, with a wedge shape, thinner in the peripapillary region and fanning out to the periphery. It is more easily detected when the surrounding NFL is thicker. Slit like defects are common and do not indicate pathological NFL loss. Slit defects are seen in up to 10 per cent of normal eyes. They can be distinguished from the wedge defects by their smaller size and by noticing that they do not reach up to the disc rim (Fig. 6.7).

In advanced cases, the superior and inferior NFL striations are lost though the papillomacular bundle is preserved thus creating an image of darkness at the superior and inferior poles, while the papillomacular bundle appears brighter. In end-stage, even most of these fibres are lost, and the fundus has a uniform dark appearance. Occassionally, a few remaining nerve fibres will remain and can be monitored for change.

Examining the NFL is particularly useful in trying to distinguish between glaucoma suspects and the glaucoma damage. Once a diagnosis of glaucoma is made, correlation of visual field defects with NFL defects is helpful. Another use of NFL evaluation is in distinguishing between large physiologic cupping and actual glaucomatous optic disc cupping.

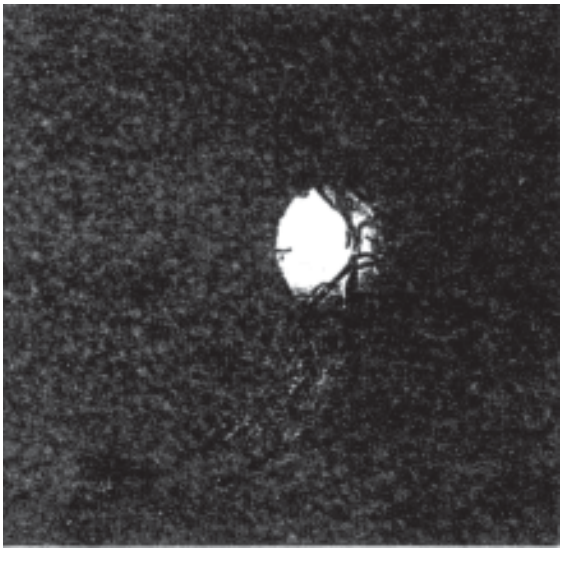


Fig. 6.7: Superior wedge defect in NFL

Scanning Laser Polarimetry to Assess the NFL

RNFL defects may be an early sign of glaucoma, preceding ONH and visual field changes. Though actual retinal ganglion cell atrophy cannot be visualised clinically, it can be detected indirectly as diffuse and/or wedge-shaped RNFL defects.

Scanning laser polarimetry provides *in vivo* quantitative assessment of the peripapillary RNFL. This method is based on the assumption that the NFL is birefringent. This birefringence causes a change in the state of polarisation, also known as “retardation”, and can be quantitated by determining the phase shift between the extraordinary and ordinary beams and is linearly related to the thickness and optical properties of the RNFL.

The scanning laser polarimeter nerve fibre analyzer (NFA) is a confocal scanning laser opthalmoscope (CSLO) with a polarisation modulator, a cornea polarisation compensator, and a polarisation detection unit. The light source, a polarization modulated laser beam (wave length 780 nm), is focussed onto one point of the retina by the optical media of the eye. Due to the parallelism of the neurotubules of the retinal nerve fibres, the RNFL shows birefringent polarisation (retardation) of the light passing through it. The polarised light penetrates the birefringent NFL and is partially reflected from deeper layers of the retina. The light emerging from the eye and collected by the instrument is separated from the illuminatinng light by a nonpolarising beam splitter. Later, the polarisation state of the light is analysed by the polarisation detection unit. The electrical outputs of the polarisation detection unit are digitised and stored in the memory of a personal computer for later evaluation.

A scan unit deflects the illuminating laser beam to an adjacent retinal position where the above procedure is repeated. A complete scan consists of 256 by 256 individual retinal positions (pixels). For clinical use, a field of view of 15° is employed. These 65,536 data sets are acquired in 0.7 seconds. During this period, a compensatory device neutralises anterior segment to isolate polarisation measurements of the retina.

Immediately after getting the data, a computer algorithm calculates the amount of retardation at each measured retinal position. A retardation map describes the changes in the state of polarisation at each location within the field of view. Processing time is about 15 seconds. The map consists of 256 by 256 pixels, and the value of each pixel represents the amount of retardation. For qualitative comparison, each pixel is colour-coded with yellow and white as high retardation and dark blue as low retardation. Usually three images are obtained from each eye to create a baseline image (Fig. 6.8, Plate 9).

Retardation information is obtained at user-defined distances from the disc margin and concentric with it. This disc margin is established by an examiner who outlines a circle or ellipse placed around the inner margin of the peripapillary scleral ring. Retardation values along the concentric circle/ellipse are shown in an adjacent polar co-ordinate plot; co-ordinates in this plot that are further away from the circle represent higher retardation. Mean retardation along each circle is recorded in 16 equal sections at 22.5° intervals and transferred to an external computer for further analysis.

One advantage of the scanning laser polarimeter is that it provides realtime measure of the RNFL with recduced need for pupil dilatation and clear media. Unlike photography, the scanning laser polarimeter allows assessment of retinal nerve layer during the clinical visit.

Optical Coherence Tomography (OCT)

OCT permits high resolution cross-sectional imaging of biological tissue using light. It utilises interferometry and near infrared, low coherence light to achieve a resolution of about 10 microns in the eye. A transverse sequence of longitudinal optical ranging measurements is used to construct a false colour tomographic image of tissue microstructure, which appears remarkably similar to histologic section. A circle of 3.4 mm is scanned to create cylindrical sections of the retina around the optic nerve. The circular scan results in the cylindrical retinal cross-section. OCT thus serves as a means of both imaging NFL and directly quantifying NFL thickness. The cross-sectional image of the retina is examined for focal NFL defects, localised regions of NFL attenuation, and diffuse NFL atrophy. NFL thickness is quantitated by an automated computer algorithm that identifies the anterior and posterior borders of the NFL, and the data are summarised by clock hour, quadrant, and overall.

The OCT device is manufactured by Humphrey Instruments (San Leandro, California). There is a fibreoptic delivery system which couples the OCT unit with a slit lamp biomicroscope for *in vivo* tomography of the retina. Computer-driven galvanometric scanners permit manipulation of the beam directed into the eye. The beam passes through a 78 D volk lens for indirect imaging and the beam focus is coincident with the slit lamp image plane, which allows visualisation of the eye with a near-infrared CCD camera while scanning. The tomogram is displayed in realtime on a computer monitor, and the video image is similarly shown on a separate video display. This system acquires a 3 mm depth by 100 axial scan spaced approximately 110 microns apart, wide image in under 1 second.

An image processing computer programme is available to quantitate total retinal thickness and retinal nerve fibre layer (RNFL) thickness. Retinal thickness is qantitated by computer for each axial scan in the image as the distance between the first reflection at the vitreoretinal interface and the anterior boundary of the red, reflective layer corresponding to the RPE and choriocapillaris. NFL is assumed to be correlated with the extent of the red, highly reflective layer at the vitreoretinal interface. Boundaries are located by searching for the first points on each scan where the reflectivities exceed a certain threshold.

Thresholds are separetely determined by the computer for each axial scan in the image as two-thirds of the maximum reflectivity in each smoothed axial scan evaluated on a logarithmic scale. Linear interpolation is performed to remove gaps in the boundaries resulting from shadowing due to blood vessels. The boundaries chosen by the computer are then overlaid on a false colour

display of each image. The NFL and RPF boundaries are highlighted with a blue line, and the superficial surface of the retina is denoted with a white line. Retinal and NFL thickness are reported as averages over each quadrant, as average for each clock hour, and as averages over the entire cylindrical section. Thickness can be displayed individually for each axial scan as well (Figs 6.9 and 6.10, Plate 10).

Quantitative measurements made with OCT of NFL thickness correlate well with clinical parameters such as visual fields and NFL appearance. OCT shows a significant difference in NFL thickness between normal and glaucomatous eyes, particularly in the inferior quadrant.

PROVOCATIVE TESTS

For Angle Closure Glaucoma

Physiological (darkroom prone test) The IOP is measured and recorded. The patient lies in the prone position in a dark room awake for one hour. After one hour, the IOP is measured and gonioscopy performed. A positive result is an increase of 8 mm Hg or more in IOP, in presence of a closed angle.

Pharmacological (mydriatic) test The IOP is measured and recorded. A short acting mydriatic (eucatropine 5 per cent or hydroxyamphetamine 5 per cent) is instilled into one eye. When the pupil is dilated to 5 mm, the IOP is measured at 10 minutes interval for one hour. The positive result is an increase of 8 mm or more in IOP in presence of a closed angle.

The mydriatic test has the following shortcomings:

i. it may precipitate a severe attack of PACG;
ii. as mydriatics are also capable of causing elevation of IOP in an eye with an open angle, gonioscopic evidence of angle closure is mandatory if the result is to be interpreted as positive;
iii. a negative result never means that the angle is incapable of closure in near future; and
iv. a positive result means that the angle is capable of closure but it does not mean that closure is imminent or inevitable.

For Open Angle Glaucoma

Water loading tonography It is not of much use nowadays.

Drinking 1 litre of water while fasting, elevates IOP. The maximum increase in IOP and decrease in outflow facility occurs 45 min after water consumption. The response is greater in eyes with open angle glaucoma.

To minimise the effects of water loading, the ratio P/O/C is used. A P/O/C ratio more than 100 after water drinking occurs in 95 per cent of eyes with untreated glaucoma and in less than 2.5 per cent of normal eyes. A ratio more than 138 occurs in 73 per cent of glaucoma eyes and in only 1.5 per cent of normal eyes.

Digital tonometry The intraocular tension is estimated by palpation of the eyes with fingers while the patient is allowed to look down. The sclera is palpated through the upper lid beyond the tarsal plate (Fig. 6.11).

Fig. 6.11: Digital tonometry

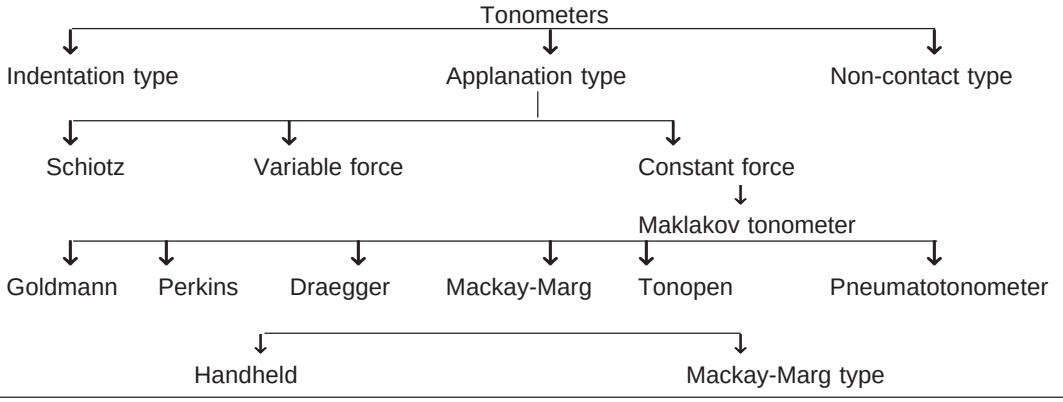
TONOMETRY

STERILISATION OF TONOMETER

The center for infectious disease in Atlanta, currently recommends the use of gloves in all ophthalmologic examination. All devices that come into contact with the eye and tears should not be reused without sterilisation. The spread of AIDS has renewed the needs for adequate sterilisation of instruments. Following methods must be followed:

1. The tip must be wiped with 70 per cent ethyl alcohol.
2. The instrument must be soaked in 3 per cent hydrogen peroxide.
3. The instrument must be soaked in 0.5 per cent sodium hypochlorite.

Chart 6.1: Types of tonometer



4. The disinfectant must be washed completely from the instrument to prevent possible injury to the cornea.

Ethanol wiping with air drying or soaking for 5 to 10 min with the other agents, produces effective viral deactivation.

TYPES OF TONOMETER

The main types of tonometer are the following (Chart 6.1):

Indentation (Schiotz) Tonometry

The instrument has a body with a handle and numerical scale (Fig. 6.12, Plate 11). A footplate with a movable plunger comes into contact with the anaesthetised cornea. The degree to which the plunger indents the cornea is indicated by movement of the needle on the scale (Fig. 6.13, Plate 11). A 5.5 gm weight is permanently fixed to the plunger. Additional weights (7.5, 10 or 15) can be added to the plunger to increase the weight of the indentation.

Before using the tonometer it must be checked. The zero-check disc is placed on a flat surface. The clean tonometer is placed perpendicularly on the metal disc with the entire weight of the instrument resting on the disc without any support by the handle. The scale reading must be zero. Repeat checks with other weights should also be zero.

Method The patient must be placed in a supine position and instructed to look at an overhead target with the eye not undergoing measurement. The eyelids are gently separated without pressure applied on the globe. The eyelids must not touch the tonometer footplate. The footplate with 5.5 gm weight is then placed on the anaesthetised cornea. Proper vertical positioning of the instrument allows free movement of the plunger and the indicator needle in response to ocular pulsations. If the scale reading is 4.0 or less, additional weights are added to the tonometer so that the measured scale reading is in a more accurate area of the calibration curve. The scale reading and weight used are recorded. The IOP is obtained from the conversion table.

The tonometer must be disassembled and cleaned after each use. The weight is either unsnapped or unscrewed from the plunger, which is removed. The plunger and barrel are rinsed with distilled water and wiped dry.

Discussion The plunger indents the cornea resulting in an artificial elevation of the baseline IOP (Po) to a new value (Pt). Pt with Schiotz tonometer often is very much higher than Po meaning that large corrections are required in calibration curves for IOP. (In applanation tonometry there is small displacement of aqueous and Pt is only 3 per cent greater than Po). Po is estimated from tables obtained from experiments on enucleated eyes in which the IOP was set and Schiotz value determined. The relationship between pressure and volume changes can be

expressed as a numerical constant, the coefficient of ocular rigidity. Ocular rigidity is an expression of the distensibility of the eye. The Friedenwald nomogram for estimating the coefficient of ocular rigidity is based on two tonographic readings with different Schiotz weights. The coefficient of ocular rigidity can also be estimated from the difference between applanation and Schiotz indentation pressure readings. The 1948 conversion tables are based on an average ocular rigidity of 0.0245 whereas the 1955 tables are on 0.0215.

Sources of error These are as follow:

1. A steeper or thicker than normal cornea will result in a greater displacement of fluid and a falsely low IOP.
2. Patient variation from the average co-efficient of ocular rigidity used to generate the conversion tables will result in an incorrect IOP. A higher than "average" rigidity results in false high IOP, e.g. in high hypermetropia, with long-standing glaucoma and with vasoconstrictors. A lower than "average" rigidity results in false low IOP, e.g. in myopia, during a water provocative test, by miotics (cholinesterase inhibitors) and following ocular surgery including retinal detachment repair and cataract removal.

Critical design standards These are as follow:

1. Footplate should have a concavity of 15 mm radius of curvature.
2. Framework should weigh 11 gm.
3. Plunger should be 3 mm in diameter and weigh 5.5 g, including the force of the lever resting on the top of the plunger.

Applanation Tonometry

Performed either by flattening the cornea to a predetermined area and measuring the required applanating force or by using a constant applanating force to flatten the cornea to a variable area (Fig. 6.14, Plate 11).

Goldmann applanation tonometer: This is a variable force tonometer consisting of a double prism with a diameter of 3.06 mm. The tonometer is mounted on a standard slit lamp in such a way that the examiner's view is directed through the centre of a plastic double prism, which is used to applanate the cornea. Two beam splitting prisms within the applanating unit optically convert the circular area of corneal contact into semicircles. The prisms are adjusted so that the margins of the semicircles overlap when 3.06 mm of cornea is applanated. The biprism is attached by a rod to a housing which contains a coil spring and a series of levers that are used to adjust the force of biprism against the cornea (Fig. 6.15).

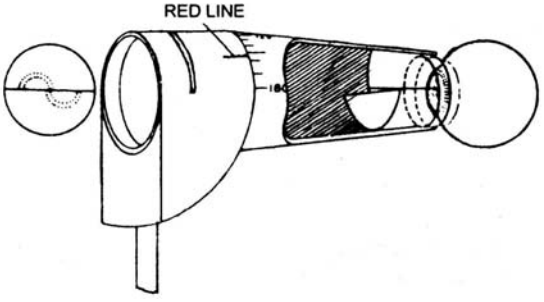


Fig. 6.15: Split field prism head of the Goldmann applanation tonometers. The two prisms produce a displacement of the two half fields of 3.06 mm with respect to one another. Thus, when the inside edges of the semicircular bands representing the fluorescein filled tear meniscus are aligned by varying force on the applanation head, the applanated area is exactly 6.06 mm in diameter

Technique These are as follow:

1. The prisms must be cleared with cotton soaked in alcohol.
2. The instrument is set up in the position. The red axis mark of the prism is kept at 0^{o}–180^{o} axis.
3. The patient is positioned at the slit lamp with the forehead firmly against the headrest and looking straight ahead.
4. Topical anaesthetic (4% xylocaine) is instilled into the lower fornix.
5. The tear film is stained with fluorescein and the patient is asked to blink—failure to use fluorescein results in significant underestimation of IOP—excessive fluorescein may result in overestimation of IOP.
6. With the cobalt blue filter and the brightest beam projected obliquely at the prism, the prism is centred in front of the apex of the cornea.

7. The dial is present at '1' or higher (between '1' and '2') i.e. between 10 and 20 mm of Hg.
8. The prism is advanced until it just touches the apex of the cornea and the situation is viewed through the oculars of the slit lamp.
9. When the prism touches the apex of the cornea, two greenish yellow semicircles are seen—these represent the fluorescein stained tear film, touching the upper and lower outer halves of the prism.
10. The dial is adjusted until the inner edges of the two semicircles just touch—this indicates that the cornea has been perfectly flattened. The overlapping semicircles indicate excess applanating force and separated semicircles indicate insufficient applanating force.
11. IOP is determined by reading the number on the dial and multiplying by 10.
12. If the semicircles are elliptical (which indicates marked corneal astigmatism) the prism is rotated from the horizontal position so that the red axis mark on the biprism is 45^o between the major axes of the corneal astigmatism. For example, if corneal astigmatism is at 160^o the red axis is placed at 115^o midway between 160^o and 70^o.

Sources of error These are as follow:

1. Too wide a meniscus cause false high reading.
2. Improper vertical alignment leads to false high reading.
3. A high degree of corneal curvature results in high reading, i.e. 1 mm Hg increase for every 3 dioptres of increased corneal power.
4. Thin corneas give a false low reading and thick corneas a false high reading.
5. An irregular cornea will distort the mires and interfere with the accuracy of the reading.
6. Corneal oedema results in irregular mires and false low reading.
7. Corneal epithelial defects with fluorescein staining result in poor applanation mires and a poor pressure reading.
8. External pressure on the globe, either the squeezing of the eyelids or pressure by the examiner or by restricted extraocular muscles (e.g. thyroid myopathy, blowout fracture of the orbit) results in false high pressure readings.
9. Valsalva manoeuvre or compression of the jugular veins will increase episcleral venous pressure and result in a high IOP.

Complications Following complications are faced in this tonometry:

1. Corneal abrasion.
2. Allergy to topical anaesthetics or to fluorescein.
3. Transfer of bacterial or viral contamination.

Tonometer check 'Force adjustment' of the tonometer should be checked at regular intervals. The balance bar provided along with, is clipped over the main pivot on the body of the instrument. The 'force adjustment' knob is set to zero. The bar is decentred to index at one of the black lines, which result in movement of the prism arm backward. The adjustment knob is rotated until the prism moves.

i. at a scale reading of 2 (i.e. 20 mm of Hg) if the bar is decentred to the first black line.
ii. at a scale of 6 (i.e. 60 mm of Hg) if the bar is decentred to the black line near the end of the bar. The force adjustment is made for both marks on the bar. The zero force applied position is checked by rotating the adjustment knob (without the balance bar) to zero, which should result in free movement of the prism arm. The check of tonometer ensures proper calibration of the force adjustment mechanism.

Other Applanation Tonometers

i. Handheld Goldmann Type Tonometers

Portable units which do not require slit lamp, are available and they have a counterbalanced prism arm that permits the instruments to be used in the vertical and horizontal position.

A. Perkins applanation Tonometer It utilises the same biprism as Goldmann instrument. The only difference is that they have a battery powered light source with a cobalt blue filter. The applanation force is varied manually via a rotating dial (Fig. 6.16, Plate 11).

B. Draeger applanation Tonometer It utilises a specialised prism that maintains the Goldmann

3.06 mm applanating diameter. They have an electrically powered light source. Applanation force is varied by an electric motor connected to the prism-arm via a rotating switch.

ii. Mackay-Marg Tonometer

This instrument is a combined applanation and indentation tonometer. The probe tip consists of a hollow probe with an inner 1.5 mm diameter movable plunger. The probe is brought into contact with the anaesthetised cornea and flattens the cornea. The force required to align the flat plate of the plunger flush with the surrounding probe is recorded and this represents the pressure required to bend the cornea so that the plunger is flushed with the probe. This method tends to overestimate the actual IOP. One advantage of main instrument is that accurate IOP estimation is obtained in eyes with corneal oedema.

iii. Tonopen Tonometer

The tonopen is portable and battery operated. It uses principles similar to the Mackay-Marg tonometer. The tip has a strain gauge that is activated when it touches the cornea. The built-in microprocessor logic circuit senses a trough force similar to that in Mackay-Marg tonometer and registers that until an acceptable measurement is achieved. If the logic circuit does not sense a proper shape to the force curve, that particular measurement is rejected. Four to ten acceptable readings are averaged to give a final IOP which is displayed as a digital read-out. The number of readings needed to get an average reading is variable depending on how close the individual readings are to each other.

The probe tip is placed perpendicularly to the cornea until the cornea is just indented. An audible click indicates that the measurement is acceptable. This process is repeated two to ten times until a beep indicates that enough data have been collected to determine a statistically valid average reading. The end point is determined electronically, not optically, and the average of the measurements is displayed in a quartz crystal digital display. The standard deviation in terms of the percentage of the displayed average pressure reading is displayed by a bar over the 5 per cent, 10 per cent, 15 per cent and 20 per cent markings. The tip of the tonometer is protected by a disposable latex cover.

iv. Pneumatotonometer

The pneumatotonometer has an air-pressure — sensitive probe that contacts the cornea. The sensing tip has an outer diameter of 0.25 inches and is covered by a plastic diaphragm with pressurised air filling the central chamber and the diaphragm. Each instrument and probe requires a calibration check against Goldmann applanation reading since probes and transducers vary. The tip is applied to the anaesthetised cornea and force is applied to bend the cornea. The force required to deflect the cornea is converted by a transducer to a pressure reading. The intraocular pressure tends to be higher with the pneumatotono-meter than with Goldmann applanation tonometer (Fig. 6.17, Plate 11).

v. Maklakov tonometer

It is based on the principle that IOP can be determined by measuring the diameter of the corneal area flattened by a fixed weight. The tonometer is a dumb-bell-shaped metal cylinder with end plates of polished glass 10 mm in diameter. Identical instruments weighing 5, 7.5, 10 and 15 gm are used to measure the IOP. A thin layer of dye is spread onto the bottom of either end plate, and the instrument is allowed to make contact with the anaesthetised cornea of a supine patient for a second. A circular white imprint on the end plate results, the diameter of which is measured with a transparent plastic measuring scale to 0.1 mm. If the imprint is oval, either the cornea is astigmatic or the tonometer was moved during the applanation.

Pressure (P) in gm/mm is derived from the formula,

$$P = \frac{W}{\pi r^2}$$

where W = cylinder weight in grams, r = radius of the imprint in millimeters. A conversion to mm of

Hg can be made by dividing this value by 136. Alternatively, conversion tables of different diameters using columns of corresponding weights have been devised. Correction must be made for ocular rigidity, the force required to bent the cornea, the force of the tear film surface tension, and tear impingement into the thin layer of dye.

Maklakov tonometer is popular in Russia and China but has not gained wide acceptance in other countries.

Hand held Non-contact Tonometer

It flattens the corneal apex by means of a jet of air, generated by a solenoid-activated piston, which increases linearly as time passes by. The system consists of a transmitter which directs a collimated beam of light at the corneal apex and a receiver and detector, which accepts only parallel rays of light reflected from cornea, determines the time to flatten the cornea. The various time intervals are converted to an intraocular pressure and are displayed on a digital read-out in mm Hg (Fig. 6.18, Plate 12).

TONOGRAPHY

It is a clinical technique used to measure the aqueous humor outflow facility noninvasively. It is based on observation that external pressure on the eye (either massage or the weight of a Schiotz tonometer) with time causes a lowering in intraocular pressure. Tonography quantitates this effect by utilising electronic techniques to measure intraocular pressures continuously and the subsequent decrease in intraocular pressure secondary to the weight of the Schiotz tonometer.

Preparation

The tonography should be done in a quiet room, without disturbances while the test is in progress. Room lighting should be subdued. The patient should be placed between the operator and the tonography unit, but with all controls, panel meter and recorder in clear view of the operation. For best results, it is necessary that the patient be placed in a supine position, with his head slightly elevated. The tonography procedure requires that both the patient and the operator remain practically motionless and relaxed for at least 4 minutes. To prevent eye movements, the patient should be given a suitable fixation point for the duration of the test. Along with the required anaesthetic, a drop of 1 per cent methyl cellulose may be used to lubricate the eye and prevent change of pressure due to drying.

Always standardise the tonometer and clean its head before use. Before each procedure make sure that there is adequate chart paper for the test. At frequent intervals remind the patient to relax and to watch the fixation point. Watch to see that the patients eye remains in an upright position as it prevents loss of pulsations. Be sure that the patient is not holding his breath, as it may cause an inclining instead of declining direction in the line of the graph. If the line of the graph veers to an inclining instead of declining position near the end of the 4 minutes tonogram, ask the patient to relax, and continue the test for another half minute until the graph resumes a normal declining direction (Fig. 6.19). Allow the patient to rest his eyes for 5 minutes prior to tonography on the second eye.

Procedure

Clean and dry the tonometer plunger and footplate. Standardise the tonometer. Prepare the patient. Depress the “record data” push button to lighted position. This starts the recorder and the four-minute time period (the green light on the head of the tonometer handle indicates the commencement of the test period). With the heel of the hand resting on the forehead of the patient, hold the tonometer head just above the orbit while instructing the patient to keep his other eye gazed on a fixed object, above. Place the tonometer head gently on the patient’s cornea. Be sure that the tonometer head is vertical and centred on the eye. An accurate reading is only possible when the tonometer plunger is vertical and can move freely within the footplate.

If the initial reading is less than 4 on the lower (black) scale of the panel meter, the procedure

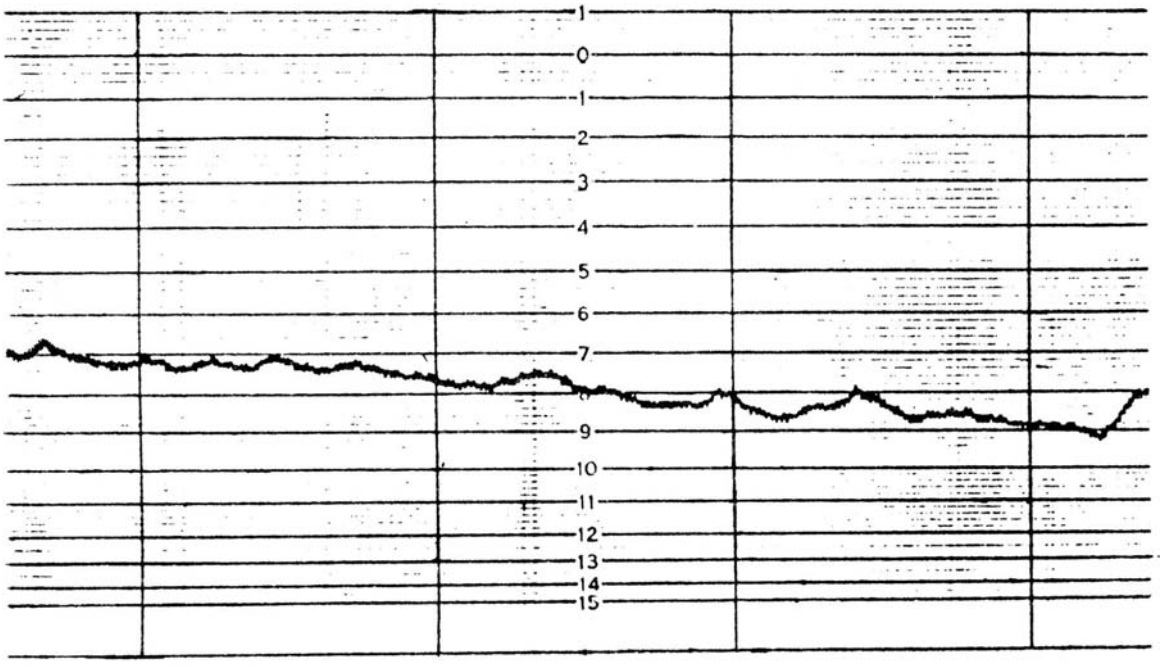


Fig. 6.19: A chart showing tracing

must be stopped and a heavier weight is placed on the tonometer head. Note the appearance of the red light on the head of the tonometer handle (replacing the greenlight). This signals the end of a standard 4 minutes tonogram to the operator without disturbing the patient (the procedure may thus be continued, if desired). After the test is completed, clean the tonometer plunger and head, replace in the storage stand and replace the stand in its original position in the cabinet (Fig. 6.20).

GONIOSCOPY

Definition

It is the clinical technique of visualisation of anterior chamber iridocorneal angle by overcoming internal reflection of light by the curved corneal surface.

Principle

Light rays coming from the anterior chamber angle exceed the critical angle of refraction at the cornea-air interface and the light rays are reflected back into the eye thus preventing visualisation of the angle. Gonioscopy eliminates the anterior corneal surface by using a contact lens with an index of refraction similar to cornea. This prevents total internal reflection at anterior corneal surface and allows the light rays to pass through the contact lens—cornea interface and after reflection at the mirror of the gonio lens, they can be visualised.

Types of Gonioscopy (Table 6.1)

Technique for Direct Gonioscopy

Principle This method uses the front curve of the contact lens to refract the light rays at the contact lens—air interface. Visualisation is achieved using a handheld binocular magnifier and an illumination source. The examination may be done with a direct ophthalmoscope as an illuminated magnifier.

Technique The patient is kept in a reclined position with the head extended. The contact lens

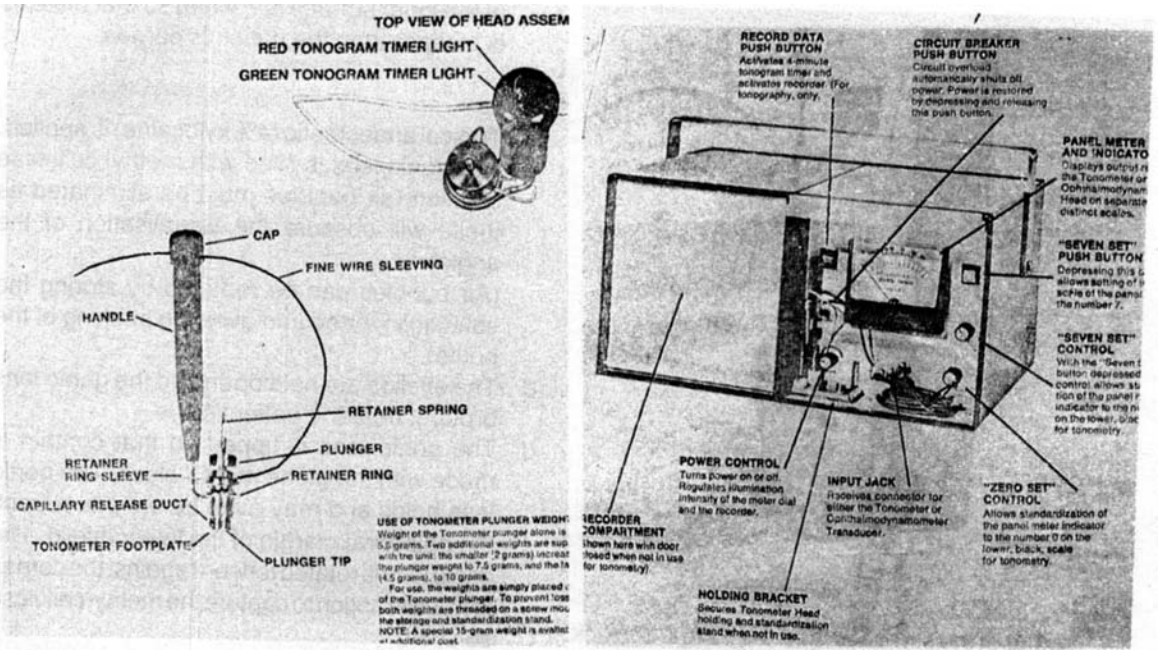


Fig. 6.20: Tonography

Table 6.1: Types of gonioscopy

Direct Gonioscopy	*Indirect Gonioscopy*
Equipments	*Equipments*
1. Koeppe lens	1. Goldmann gonio prism or Zeiss four mirror
2. Handheld microscope	2. Slit lamp
3. Barkan light	
Advantages	*Advantages*
1. Natural view	1. Slit lamp gives good optics
2. Simultaneous gonioscopy possible	2. Equipment easily available
3. Good for teaching	3. Compression gonioscopy possible
Disadvantages	*Disadvantages*
1. Cumbersome	Orientation confusion
2. Needs special equipments Done with Zeiss four mirror Differentiates appositional closure from permanent closure.	

is positioned on the anaesthetised cornea with the space between the inner surface of the lens and the cornea filled with methyl cellulose. The Koeppe contact lens may need to be stabilised by an assistant while the examiner holds the illuminator and the binocular magnifier. A gonioscope with a mounted light source can be used, thus allowing the examiner a free hand to use the gonio lens (Fig. 6.21, Plate 12).

The iridocorneal angle is viewed for 360º by shifting the position of the magnifier light source and contact lens.

Technique for Indirect Gonioscopy

Indirect gonioscopy uses a contact lens that contains a mirror to reflect the light rays to leave the lens approximately perpendicular to the contact lens-air interface (Fig. 6.22):

1. The patient's comfortably positioned at the slit lamp, sitting erect, by adjustment of the table height and chair. The patient's head is centered using the chinrest to allow full

Fig. 6.22: Gonioscope

excursion of the center of the slit beam from the 12 to 6 O' clock position. He is instructed to keep the chin in the chinrest and to press the forehead against instrument. If the slit lamp is restricted from sliding forward by the patient's chest, the patient's chair is moved back from the slit lamp and the patient is instructed to lean forward to insert his or her head in the rest (Fig. 6.23, Plate 12).

2. The examiner height and position of stool are adjusted to have him sit comfortably erect at the slit lamp. The gonio lens is held in left hand for examination of the patient's right eye and in the right hand for examination of the patient's left eye. The gonio lens is held in the examiner's thumb and index and middle fingers with the other two fingers placed gently on the patient's cheek. The wrist should be held straight and the forearm as vertical as possible or an elbow support to provide stability of the goniolens against the eye and to avoid fatigue related tremor.
3. The single mirror Goldmann gonio lens has a corneal contact diameter of 11 mm and a flatter peripheral section, extending to 14 mm, that rests on the sclera. The radius of curvature of the inner surface is 7.4 mm so that the lens is steeper than the patient's cornea.

Steps

a. Topical anaesthetic (4% xylocaine) is applied.
b. The gonio lens is filled with methyl cellulose solution (air bubbles must be eliminated as these will obscure the visualisation of the angle).
   (Air bubbles can be reduced by storing the solution inverted and avoiding shaking of the bottle).
c. The eyelids are held open and the gonio lens brought near the patient's eye.
d. The gonio lens is tipped so that contact is made with the globe at 6 O' clock. The gonio lens holds and may even be used to retract, the palpebral margin of the lower eyelid. The gonio lens is rotated forward against the cornea in a quick motion to capture the methyl cellulose solution.
e. The gonio lens is pressed against the eye creating a "suction cup" effect, which keeps the lens centred on the cornea. Pressure should be relaxed to avoid distortion of the chamber angle structure during routine examination.
f. The Goldmann gonio lens can be viewed with a direct ophthalmoscope, (at + 10.00 to + 12.00 diopters) if a slit lamp is not available.
g. The hand not holding the gonio lens is used to adjust the slit lamp microscope so that it is focussed on the image of the iridocorneal angle reflected by the mirror of the gonio lens. The sector of the iridocorneal angle across the anterior chamber from the mirror is viewed; for example, the superior angle when the mirror is at the bottom of the gonio lens. While the view in the mirror is always of the angle across the anterior chamber, this may not be 180^{o}. For example, if the centre of the mirror is at 6 O' clock the opposite angle view is 12 O' clock; however, if the gonio lens is not rotated the view from the 7 O' clock mirror is of the 11 O'clock angle, not the corresponding 180^{o} angle at 1 O' clock. The slit beam is

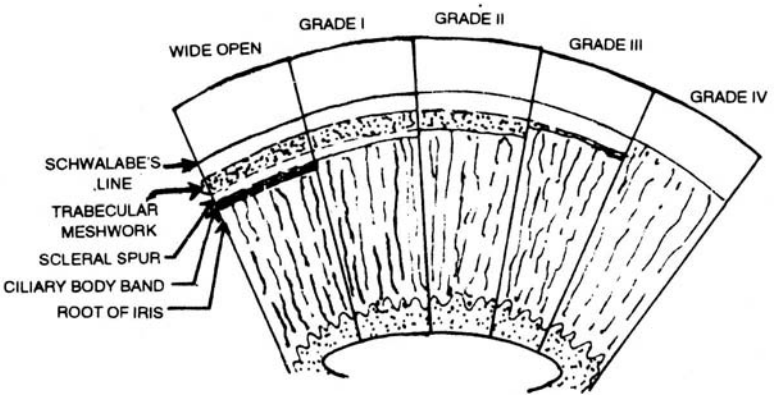


Fig. 6.24: Scheie's classification of anterior chamber angle based on the extent of visible angle structures

placed, either direct by coaxial or 15° to either side.

i. The entire 360° of the iridocorneal angle is visualised with the Goldmann gonio lens by a combination of rotating the contact lens and movements of the slit lamp.

Recording

A. Scheie's classification (Fig. 6.24):

Grading	*Gonioscopic appearance*
Wide open	All structures visible
Grade I narrow	Hard to see over the iris root into recess
Grade II narrow	Ciliary band and scleral spur are obscured
Grade III narrow	Posterior trabeculam obscured
Grade IV (closed angle)	Only Schwalbe's line visible

Grade III and IV are high risk cases.

B. Shaffer's classification (Fig. 6.25)

Grading	*Gonioscopic appearance*
Grade 0	Complete or partial closure
Grade I narrow	10° angle at recess
Grade II narrow	20° angle at recess
Grade III narrow	30° angle at recess
Grade IV open	40° or more angle at recess

(Grade II and I are high risk cases).

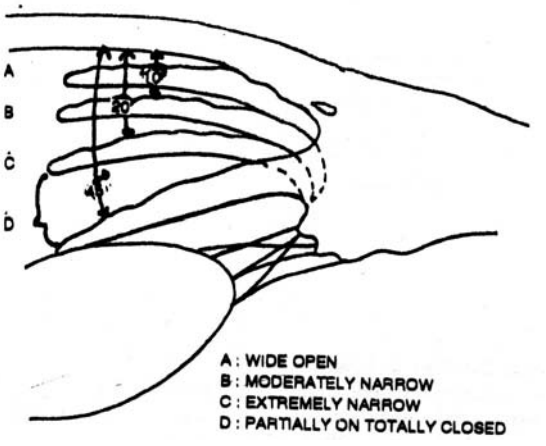
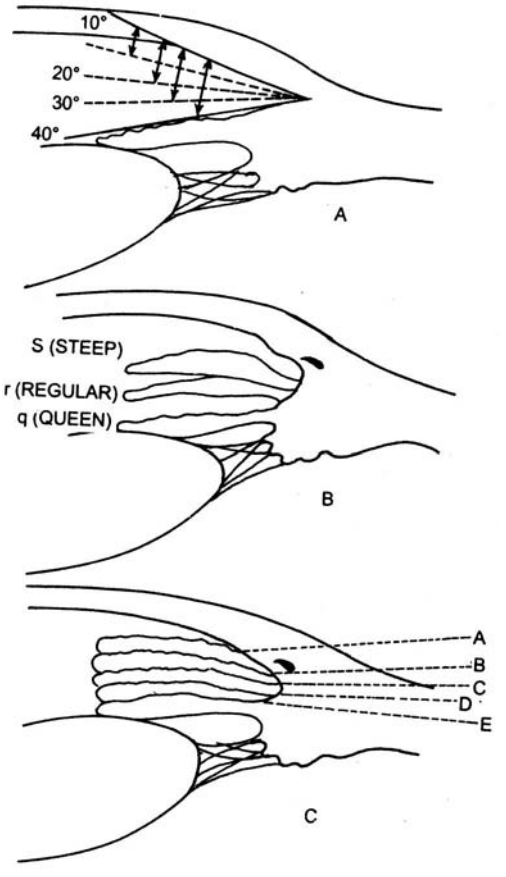


Fig. 6.25: Shaffer's gonioscopic classification of the anterior chamber angle based on the angular width of the angle recess

C. Spaeth's classification (Figs 6.26A to C):

Classification *Gonioscopic Appearance*

1. Insertion of iris root:
   - Code A — Anterior to Schwalbe's line
   - Code B — Behind Schwalbe's line
   - Code C — On the scleral spur
   - Code D — Deep
   - Code E — Extremely deep
2. Angular width of angle recess:
   Numbered from 0° to 40° (see Shaffer's classification)



Figs 6.26A to C: Spaeth's gonioscopic classification of the anterior chamber angle based on three variables. A: Angular width of the angle recess, B: Configuration of the peripheral iris. C: Apparent insertion of the iris root

3. Peripheral iris configuration:
   - Code q Queer configuration
   - Code r Regular configuration
   - Code s Steep configuration

Trabecular pigmentation

They are arbitrarily graded from 0 to IV with Grade IV representing dense pigmentation.

Abnormal angle structures (may cause secondary glaucoma).

I. Angle recession
II. Peripheral anterior synechiae
III. Angle neovascularisation
IV. Angle membranes
V. Iris processes
VI. Iridodonesis

ZEISS FOUR-MIRROR CONTACT LENS

The lens is designed to use the tear film as the interface between the contact lens and cornea. This lens has a holding fork to facilitate application of the gonio lens to the eye. The lens has a 9 mm corneal segment which rests solely on cornea and 7.72 mm radius of curvature which closely matches average cornea.

Technique

1. 4 per cent xylocaine eyedrop is applied.
2. The patient is positioned at the slit lamp so that the head is centred to allow full excursion of the slit beam.
3. The lens is applied to the cornea, using the fork handle. In a "square" configuration by holding the handle at 45^{o} angle to the eye (whereas in a `diamond' configuration by holding the handle horizontally). The square configuration is preferred as the gonio lens fits better the palpebral fissure, avoiding contact of the corner of the lens with the patient's eyelid. A plastic cup can be attached to the Zeiss gonio lens to facilitate retraction of the upper and lower eyelids.
4. The handle is held with the thumb and first two fingers while the examiner's fourth and fifth fingers rest on the patient's cheek.
5. The position of the gonio lens is maintained on the centre of the cornea by the kinesthetic guidance of the two fingers on the patient's cheek.
6. The Zeiss lens is allowed to touch the cornea, just barely to view the undistorted angle structures. This is accompanied by a slight rocking forward of the wrist of the hand holding the gonio lens.

INDENTATION GONIOSCOPY

It is a technique that enables the examiner to alter the position of the iris, relative to the trabecular meshwork in dynamic fashion. It determines, which portion of a closed iridocorneal angle is

appositionally and synechially closed. It requires use of Zeiss four-mirror gonio lens for controlled application of pressure to the globe.

Technique

1. The angle quadrant to be assessed is examined using a narrow, short slit beam with the Zeiss gonio lens and no pressure on the cornea.
2. Pressure is applied to the Zeiss lens directly towards the center of the eye.
3. If it is appositionally closed, pressure will result in deepening of anterior chamber in the angle recess. As the iris bows backwards, one can see progressively deeper iridocorneal angle structures including a previously hidden pigmented portion of the trabecular meshwork or possible peripheral anterior synechiae.
4. The technique can be used to open a closed angle during an attack of acute closed angle glaucoma.
5. A closed angle by synechiae will not open during indentation gonioscopy.

Slit Lamp Method for Estimating Peripheral Anterior Chamber Depth

1. The depth of the peripheral chamber can be estimated by the slit lamp technique of Van Herick, Shaffer and Schwartz. A thin slit lamp beam is focussed on the cornea and anterior chamber at the temporal limbus, the depth of the peripheral anterior chamber is compared to the thickness of the peripheral cornea.
2. The technique can be compared to the Shaffer's classification (Fig. 6.27):

Van Herick findings	*Shaffer's classification*
AC depth = corneal thickness	Grade IV open
AC depth = 1/4 to 1/2 corneal thickness	Grade III angle
AC depth = 1/4 corneal thickness	Grade II angle
AC depth = less than 1/4 corneal thickness	Grade I angle
AC depth = slit like (extremely narrow)	Slit angle
AC depth absent	Closed-angle

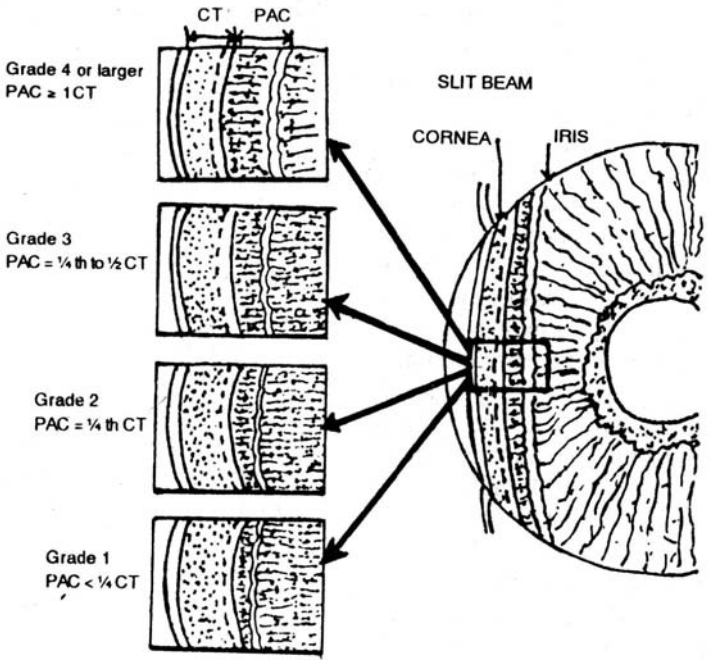


Fig. 6.27: Slit lamp technique of van Herich for estimating the depth of the peripheral anterior chamber (PAC) by comparing it to the adjacent corneal thickness (CT)

Points to note during Gonioscopy

1. Angle open/narrow/closed.
2. Anterior Schwalbe's line.
3. Trabecular band.
4. Pigmentation.
5. Schlemn's canal.
6. Ciliary band.
7. Goniosynaechiae.
8. Angle recession.
9. Angle neovascularisation.
10. Angle membranes.

GONIOGRAM

Recording and drawing of the angle in the form of a permanent record is called the goniogram. A drawing of the angle is often essential as the configuration of the angle may vary considerably; in one quadrant with this graphic method all the landmarks can be noted, including width of the angle approach, width of the trabecular band and height of insertion of the iris into the ciliary body. The goniogram accurately records the findings observed during gonioscopy including an adequate record of angle approach, trabecular width, iris insertion site, synechiae (their position and extent), tumours, pigmentation, vascularization, foreign bodies and anomalies.

The goniogram has one central dark line, which represents scleral spur. There are three lines above and three below the central reference point. In the superior quadrant, the three superior lines represent the trabeculum, and the three below the site of insertion of the iris into the ciliary body. By merely completing the two lines in the four quadrants, the width of the approach and type of angle can be judged at a glance. In addition, other abnormalities such as excess pigmentation, foreign bodies, vascularization, recession of the angle, or iridodialysis are recorded. The pupil size should also be noted, for angle appearance will depend on it.

The angle drawn in the goniogram represents the site where the quadrant was viewed in the eye by either the direct or indirect method. With direct gonioscopy these are the same quadrants as observed and with indirect they are on the opposite quadrant as viewed in the mirror, and are drawn according to the site of mirror placement (Fig. 6.28).

Colour Codes for Goniogram

1. Iris colour — blue, brown, green
2. Blood, blood vessels — red
3. Synechiae — orange
4. Membranes — yellow
5. Pigment — black
6. Depigmentation — purple
7. Angle recession — cross hatch brown
8. Iris defect (Iridectomy) — cross hatch black.

FIELD EXAMINATION

THE AMSLER GRID

It is important in testing macular function when the visual acuity is decreased or the vision is distorted. Amsler grid is a card with a flat black background. In the surface white grid of blocks are printed whose sides measure 5 mm each. There is a central white dot. The grid, held at 30 cm, covers the central 20^{o} of the retina. When there are macular defects the grid is distorted or has missing lines. Additional grids include a red printed chart and grid with diagonal lines through fixation (Fig. 6.29A). Amsler grid requires the following conditions:

1. Patient should wear full near correction. In case of bifocals the patient must look through the centre of the near addition to prevent distortion caused by the edge of the bifocal.
2. The chart must be well-illuminated and kept at 30 cm from the eye with the card parallel to the plane of the face.
3. One eye must be tested at a time. An opaque white plastic patch must be used over the nontested eye to maintain the eye's retinal adaptation.

Techniques

1. The patient fixes the white central dot.
2. Following questions are asked:
   a. Do you see a white dot in the centre of the grid?

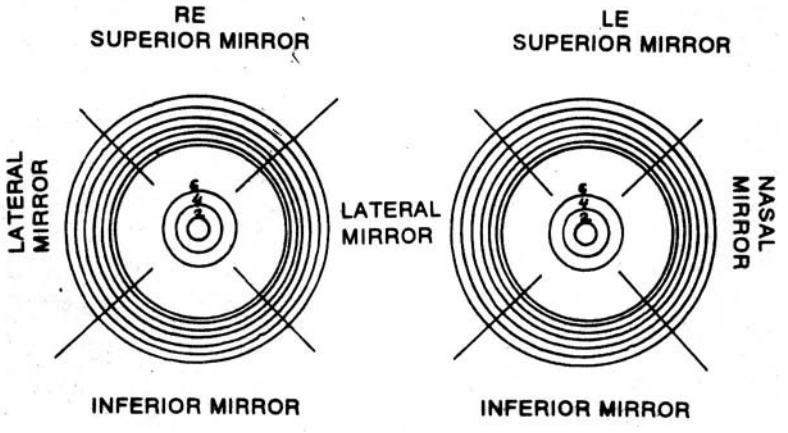


Fig. 6.28: Goniogram

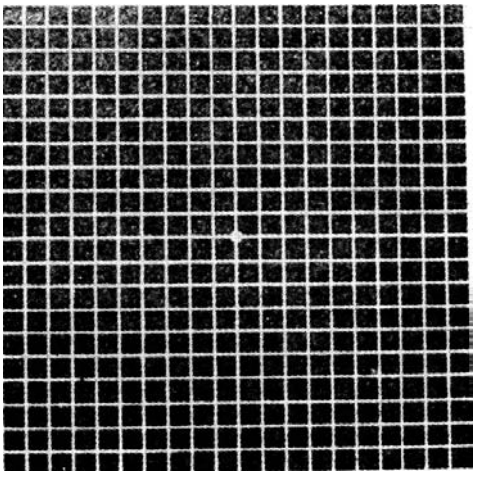


Fig. 6.29A: Amsler grid: Chart 1 →Standard chart used

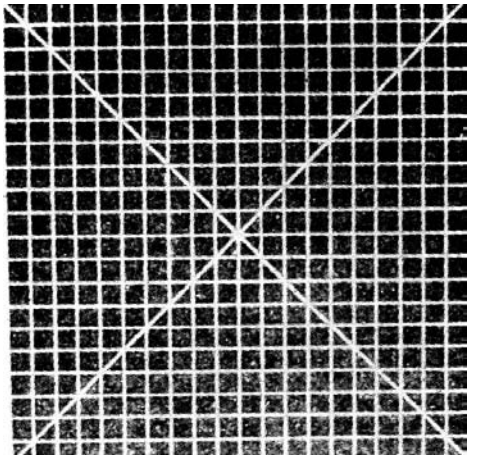


Fig. 6.29B: Chart 2 →Used in cases where the central point is not seen. The diagonal lines help to fix the centre of the square inspite of a central scotoma

   b. While looking at the white dot, can you see all four corners of the chart simultaneously?
   c. Does the grid appear to have any missing, wavy or distorted areas?
   d. Are there any areas of the grid that have an unusual appearance?
3. Note down the abnormalities (scotomas or distortions on the grid) if any, on the Amsler grid recording charts (Fig. 6.29 B to G).
4. Other eye is tested in the same manner.
5. Repeat the test using the red grid if the patient is suspected of having toxic effects from plaquenil, INH or ethambutol.
6. Use the grid with diagonal lines through fixation when the patient cannot see the white dot. Ask the patient to look where he thinks the lines cross.

Possible Problems

Diplopia (the lines appearing double). Check for the following:

a. The bifocal segment bisecting fixation.
b. Vertex distance of the reading glass from the eye (if the glasses are moved forward or backward the lines may merge).
c. Presence of a cataract (monocular diplopia).

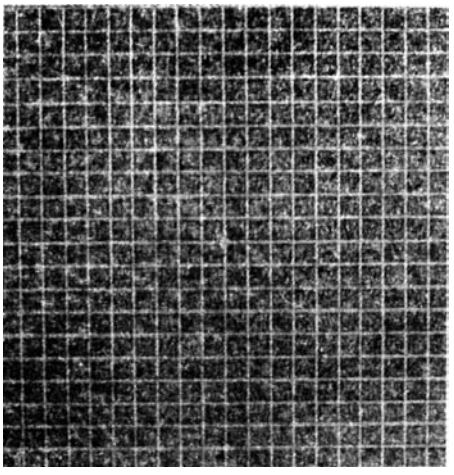


Fig. 6.29C: Chart 3 →Standard chart with red on black to be used in cases of colour-scotoma

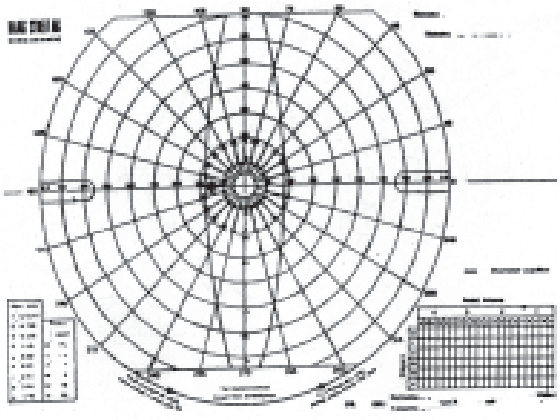


Fig. 6.29E: Chart 5 →This chart with parallel lines must be looked at horizontally and vertically. It shows up the matamorphosia

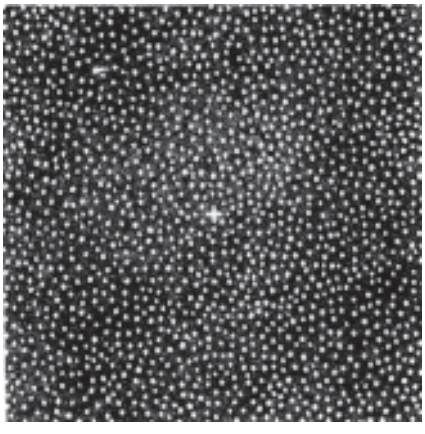


Fig. 6.29D: Chart 4 →This chart without lines reveals only the scotoma. There are no forms to be distorted

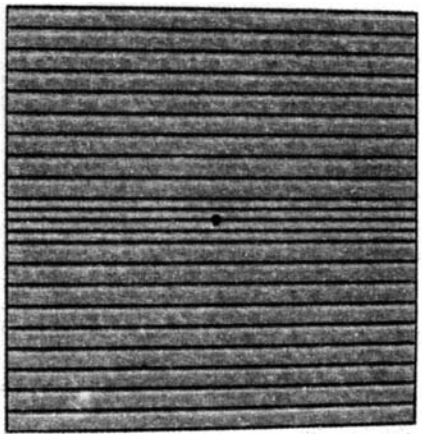


Fig. 6.29F: Chart 6 →Chart for metamorphosia which allows a more minute examination of distortion along the reading lines

CONFRONTATION METHOD

To rapidly assess the presence of gross dense field defects, the patient's field may be compared to that of the examiner's (Fig. 6.30 A and B).

The common methods of testing involve using the examiner's finger as a target.

Patient's Preparation and Method

1. The patient is placed facing the examiner. The examiner's back should be towards a white wall to eliminate distractions during the examination.
2. The examiner's knees should touch the patient's and the patient and the examiner should be at eye level.
3. The patient's opposite eye is patched.
4. The patient should be trained regarding the target, how to respond and where to fix his eye. When the patient's right eye is to be examined, he must look straight to the examiner's left eye as the fixation point and vice versa.

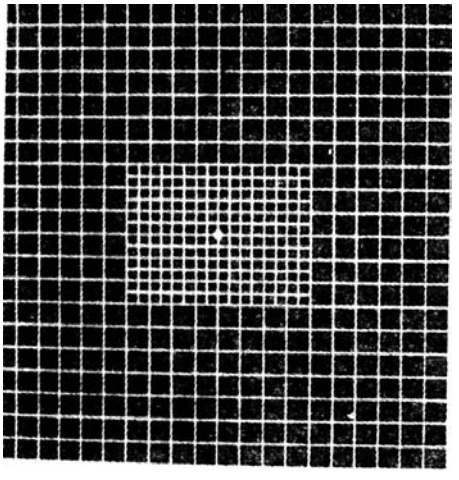


Fig. 6.29G: Chart 7 → For minute examination of juxtacentral area, where the rectangle with subdivided squares indicates the limits of the fovea

5. The target is presented along a common plane when comparing fields. Move the targets in an imaginary plane that stands upright at the region of the knees.
6. The patient and examiner should simultaneously see the target. Even the corresponding blind spot can be determined. This will confirm the validity of the test.
7. With a bed-ridden patient, confrontation testing can be performed by having the examiner lean over the bed.

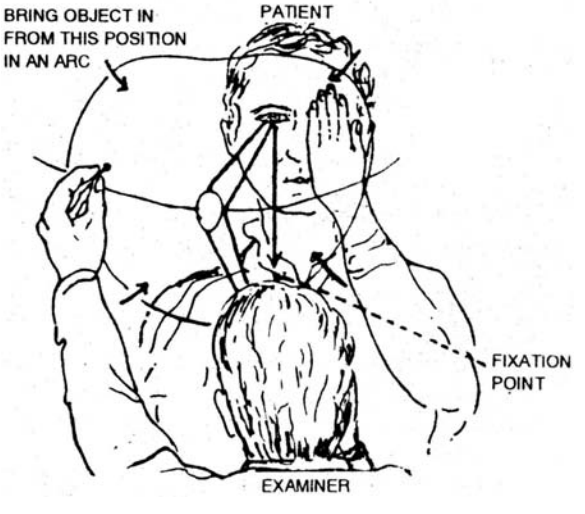


Fig. 6.30 A: Visual field testing by confrontation:
Examiner should sit opposite the patient.
Each eye is tested individually.
Throughout the test the patient is asked to look straight at the examiner's eye (the RE when testing the patient's LF and vice versa) while the other eye is kept covered. The pin should be brought in from "round the cornea" of the patient's field — from four directions

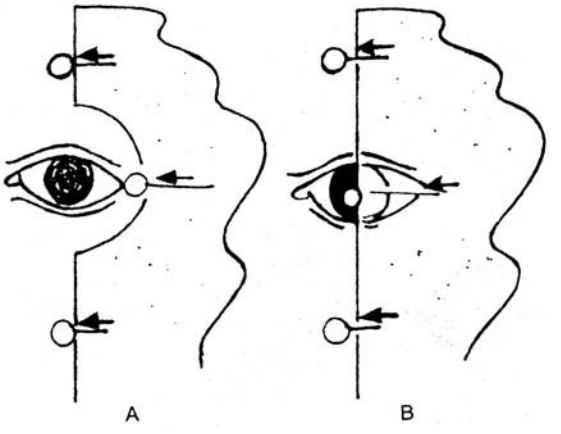


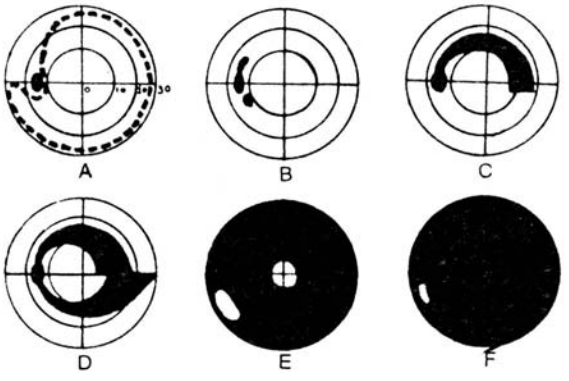
Fig. 6.30 B: Detection of macular sparing during confrontation field testing
A. "Macular sparing": Note that the pin is seen to the side of the mid-line when the macular is spared
B. "Macula splitting": If the patient and examiner are exactly aligned, the pinhead comes into the view, exactly in the mid-line of the pupil

TANGENT SCREEN PERIMETRY (SCOTOMETRY)

The tangent screen test maps the central 30° of the field. Small defects produce a larger area defect on the screen than with the bowl perimeter, but the degree measurements are the same.

The tangent perimetry can be performed on black felt screens. The one metre screen measures 2 x 2 metres square, the two-metre screen, 4 x 4 metres square. The black felt screens are stitched at 5° eccentricities and in the area of the related blind spots (Fig. 6.31, Plate 12).

Documents of field defect on the felt screen is best done with black headed beads. Fairly uniform illumination of 7.5 foot candles is required at the screen surface. Use of a lamp of 150 watt bulb



Figs 6.32A to F: Central field defects in glaucoma. (A) Baring of the blind spot, (B) Small scotomatous areas (Siedle's sign), (C) Arcuate scotoma (Bjerrum's), (D) Double arcuate scotoma (annular scotoma), (E) Temporal-central islands of vision, (F) Temporal island of vision

placed 1 metre behind the patient's head. Central fixation is on a white button for the felt screen. If the button cannot be seen tape an'X' in the centre for fixation (Figs 6.32A to F).

Patient Preparation

1. Patch the other eye with an occluder.
2. Use the patient's distance correction. Be careful when testing the lower part of the field if the patient has bifocals, depress the patient's chin to move the near segment out of the inferior central field.
3. Keep the patient at the required testing distance of 1 or 2 metres from the screen.

Performing the Examination

1. The examiner stands at the side of the screen where the field is being tested. When that half of the field is mapped, the examiner can switch to the opposite side.
2. Ask the patient to look at the central button and respond by tapping with a coin on the chair's armrest when the target is seen.
3. Place the chosen target on the stick and map the outer isopter at each stitched 30^{o} meridian. Move the target 5^{o} per second.
4. Map the central field by either moving the target along the respective meridians until it disappears and reappears or by presenting static at the junction of various meridians and eccentricities.

Techniques for the Arc Perimeter

This test should be used for the outer isopter only. No near lens correction is required.

Test Proper

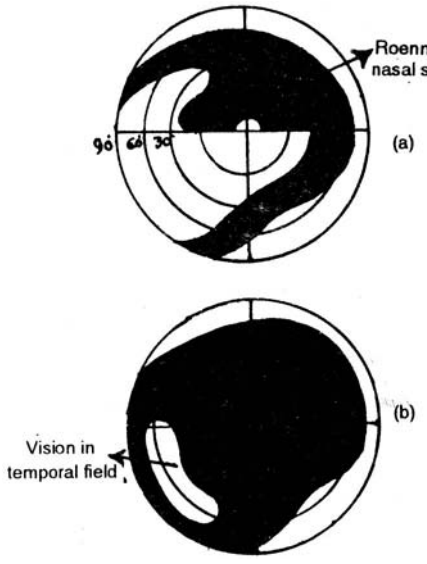
1. Patch the other eye of the patient and place his head in the correct right or left chinrest e.g. when testing the right eye use the left chinrest (Fig. 6.33, Plate 12).
2. The room should be dim enough so you can watch the patient's fixation.
3. The chart should be placed in the holder.
4. Test for the threshold target at 50^{o} temporal from fixation. Map the outer isopter along each click stop of 15^{o} around the arc.
5. The recording chart has two rings printed on the surface. The ring designated by the continuous line ring represents the right eye's normal isopter borders for a 3 mm white target and the broken line ring the left eye's isopter.
6. The same chart is used for both eyes by marking the isopter with the pin stylus. After evaluating the first eye, remove the chart and connect the isopters with the appropriate colour lines on the inside of the chart, that was against the chart holder.
7. Directly document the left eye's field on the clean chart side (Figs 6.34A and B).

GOLDMANN BOWL STATIC PERIMETRY

Static perimetry measures each retinal receptor's ability to perceive light. When the light is placed in a specific location, that receptor's threshold is measured by contrast sensitivity (Figs 6.35 and 6.36, Plate 13).

Goldmann static perimetery measures points along a specific meridian documenting the receptor's degree of eccentricity from the fovea and the stimulus intensity threshold found at each point to create the vision profile.

The "hill of vision" should be a smooth slope — except in the area of the blind spot. Subtle defects will appear as depressions in the expected normal curve. Since only one meridian is



Figs 6.34A and B: Peripheral field defects in glaucoma (A) Roenne's nasal step, (B) Vision in temporal field

examined, selection of the correct meridian is important. Usually the meridian is chosen from a previous kinetic field examination that has elicited scotomas or depressions inside the isopter border.

Setting up the Chart (Figs 6.37 A to Q)

1. End of the pantoscope arm is removed by loosening the knob just above the stylus. Slip off the old stylus. The pin tip is inserted in the slot and locked.
2. The plexiglass plate is inserted as a unit over the chart area. The pin in the lower left hand part of the plate can be placed in the left hole to co-ordinate the fixation port with foveal fixation or it can be placed in the right hole to offset the projection of light, when the stylus is on zero, to test for foveal function. Flip the four chart holding levers in place to secure the plexiglass screen.
3. A recording chart is slided under the intensity ruler. Fit the chart between the metal holder on the top of the slide with the pins in the chart holes to lock it in place. The paper chart is now above the plexiglass screen but under the ruler.
4. Place the pin of the pantoscope arm in the centre of the top metal holder and lightly move the intensity scale along the metal bar from one eccentricity to another.
5. Adjust the chart holder to the proper meridians by lifting the arms of the metal holder and turning the bar to the correct meridian setting. Lock the bar in the appropriate meridian using the holes placed every 5^o around the circumferences of the chart holder.

Setting up the Projector Device

1. Remove the light stopper plug from under the lamp housing.
2. Insert the projection device in the hole and lock it in place with the large screw.
3. Place the two polaroid filters on the projection port. By turning these filters four fixation lights can be dimmed or shut off.

Method

Testing the fovea It requires the following steps:

1. The machine should have been calibrated previously.
2. The plexiglass plate's left corner pin should be placed in the right side hole.
3. The eye not to be tested is patched and the patient is placed at the machine. To test the central 30^o appropriate near correction is placed in front of the eye. The patient is asked to look at the centre of the four dots seen on the right of fixation.
4. Central mapping is done with the size 1 or 0.25 mm square target. Using the (–) lever decreases the illumination to a level below foveal perception and the alphabet letter lever changes the intensity in increments of 0.10 log units.
5. To start with a I_2 c target at 0^o is used to measure the foveal areas. The sequences of lever changes should be made by moving the alphabet lever from (a) through (e) shifting it back to (a) and then increasing the arabic

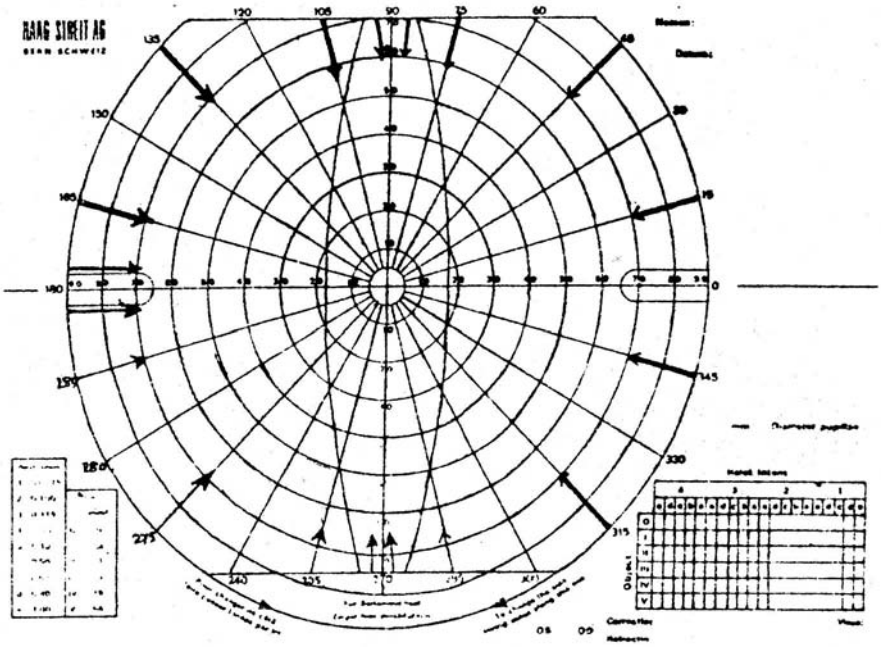


Fig. 6.37A: Arrows illustrate the directions and meridians to test when mapping the peripheral kinetic isopters

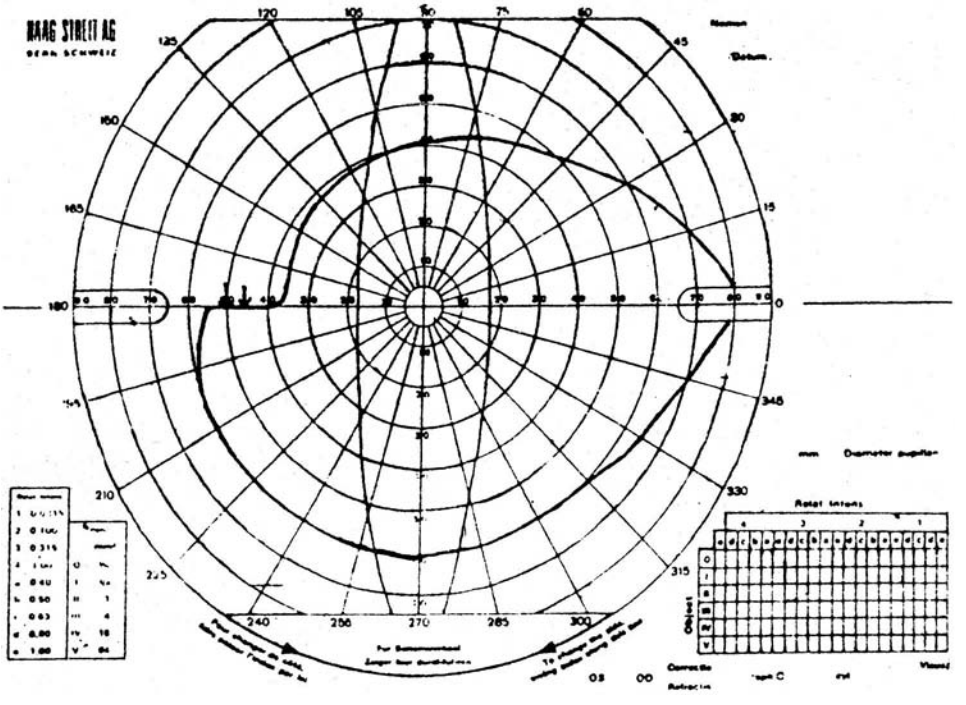


Fig. 6.37B: Mapping the horizontal step perpendicular to the 180^{o} meridian

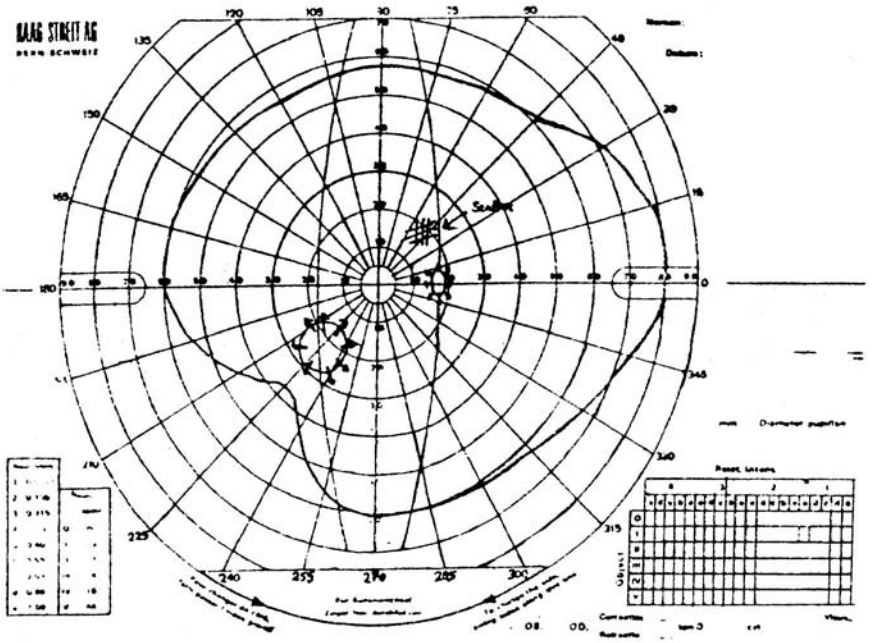


Fig. 6.37C: Mapping constricted isopters and the isolated scotomas found between the indented borders areas of scatter are indicated by crosshatching the region of "on and off" response

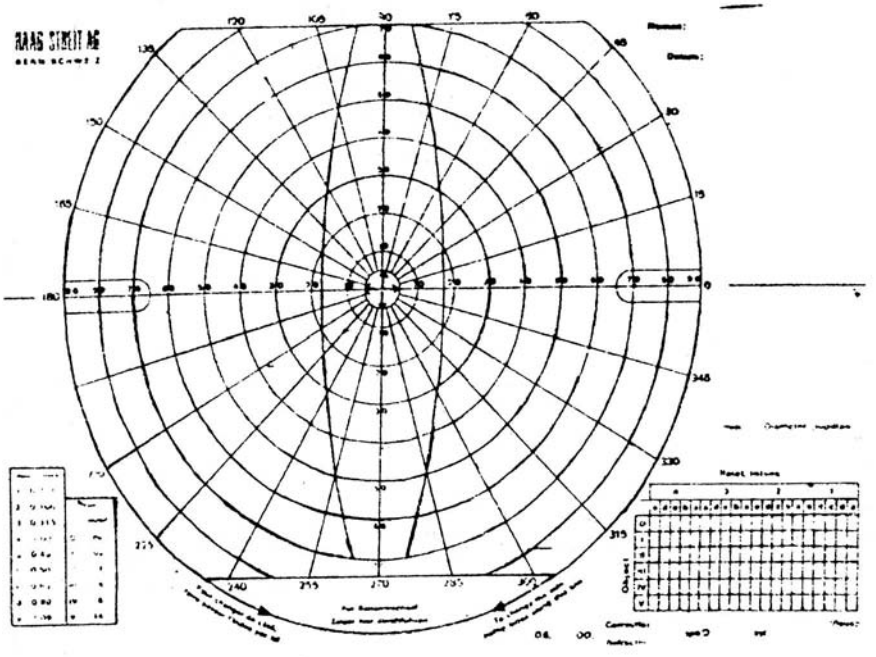


Fig. 6.37D: Static evaluation in the macular area

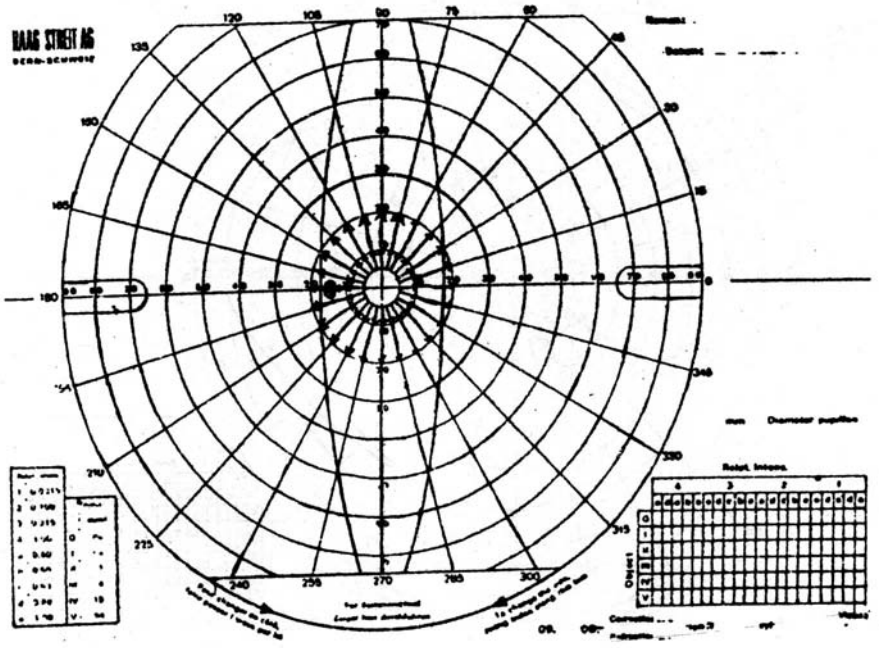


Fig. 6.37E: Static evaluation of the papillomacular area

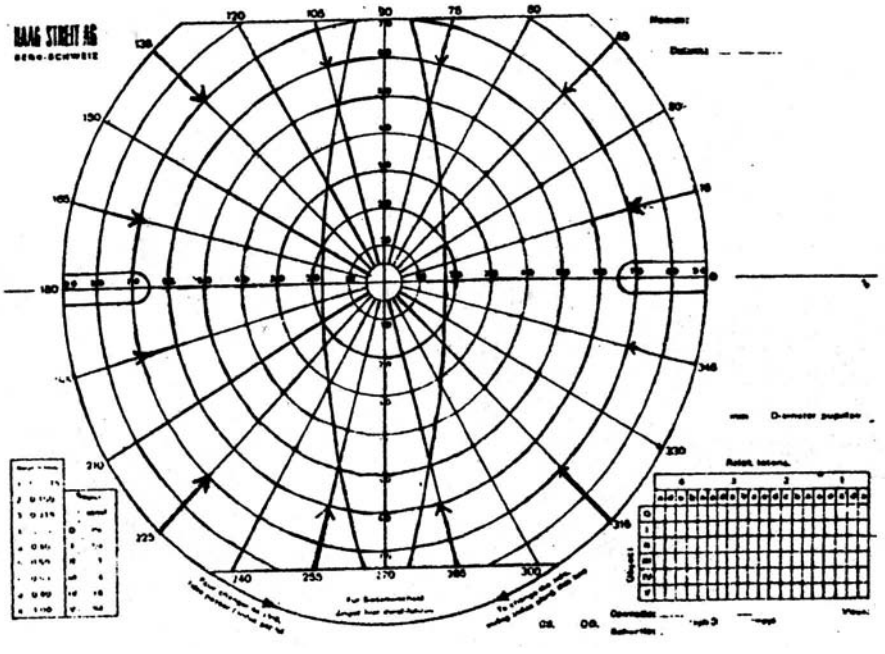


Fig. 6.37F: Kinetic-static protocols to find damage in the 30° to 60° area. Static—to find defect. Kinetic—to map defect

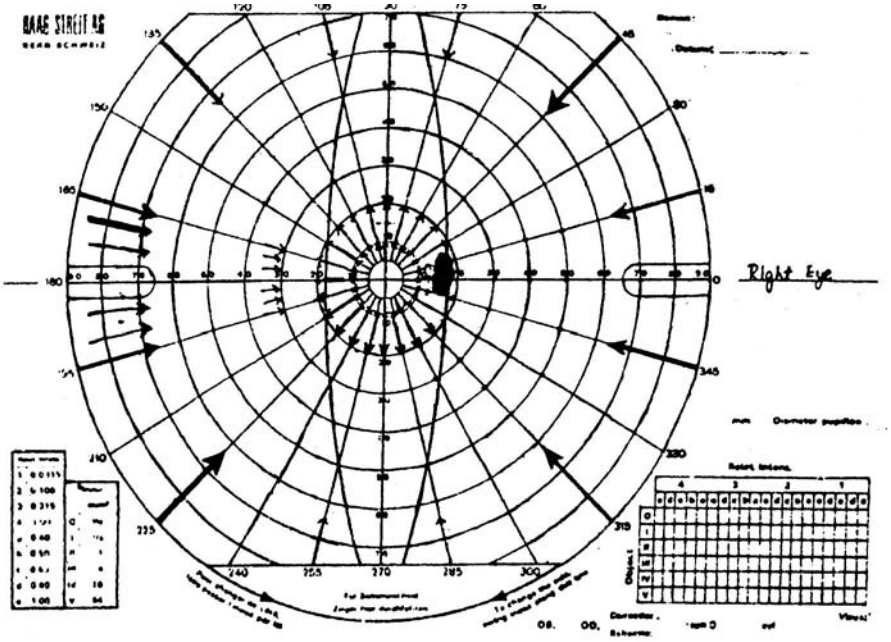


Fig. 6.37G: Standard armolyl drance testing protocol for glaucoma screening

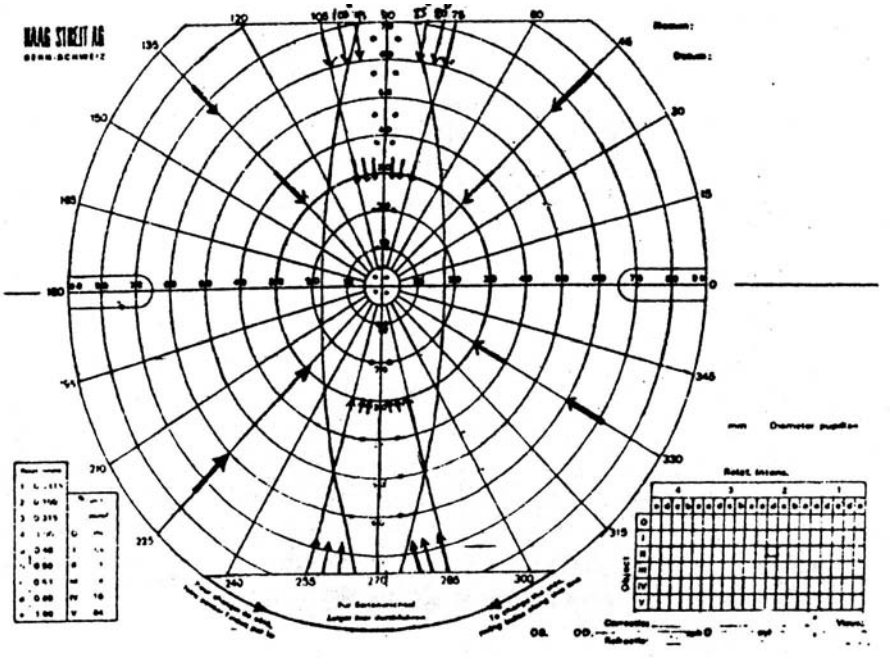


Fig. 6.37H: The protocol for neurological screening

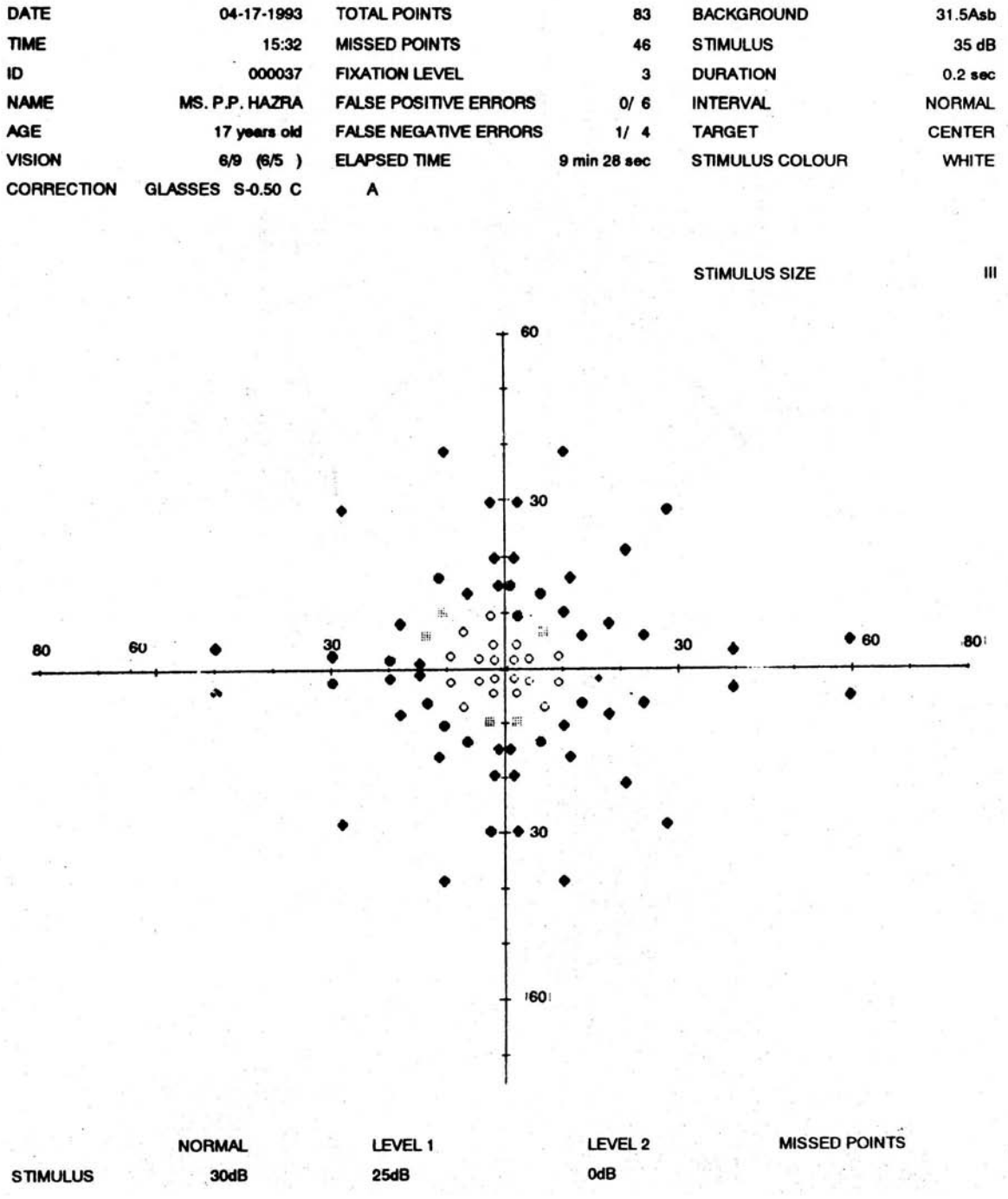


Fig. 6.37I: Screening — standard (right)

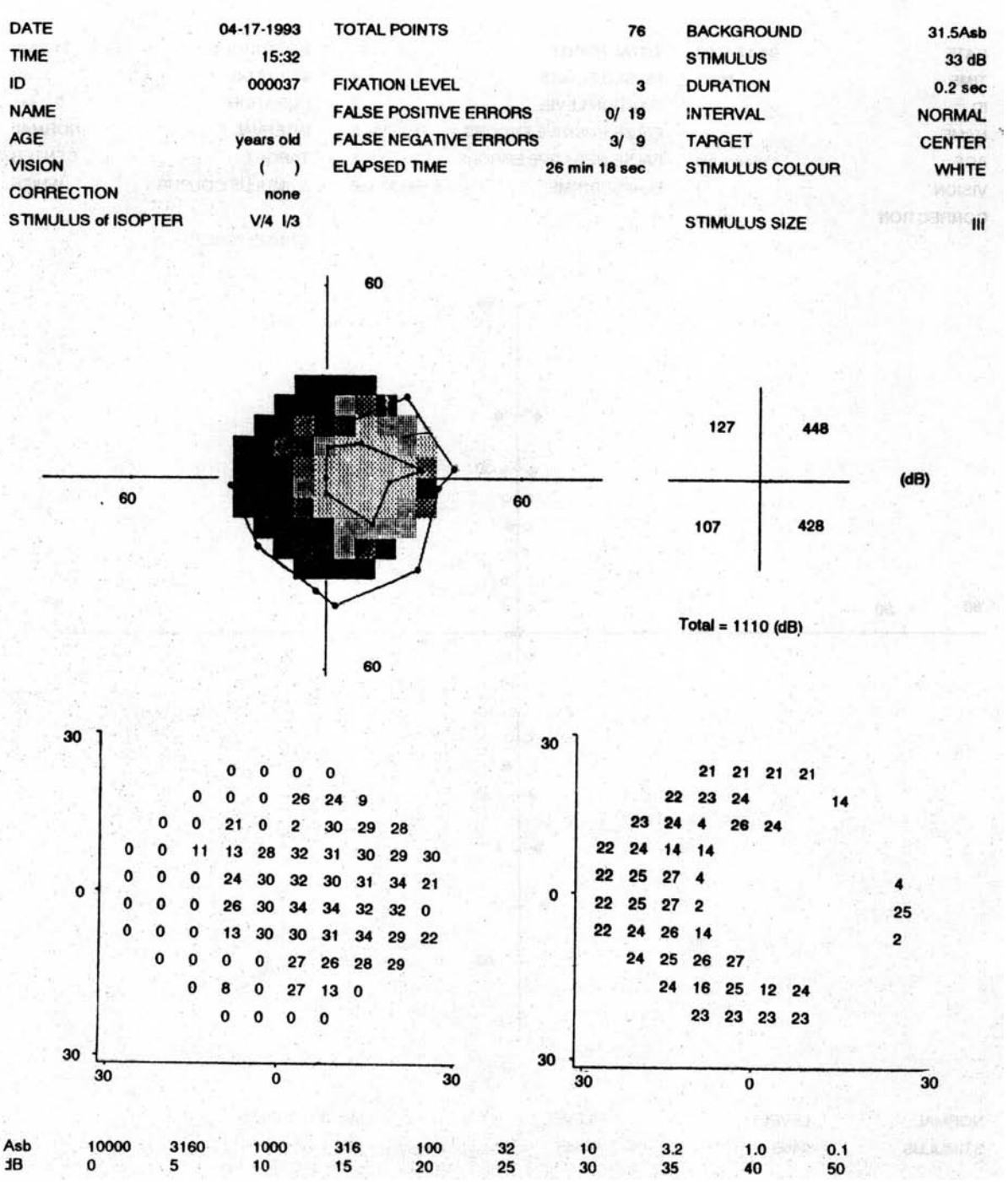
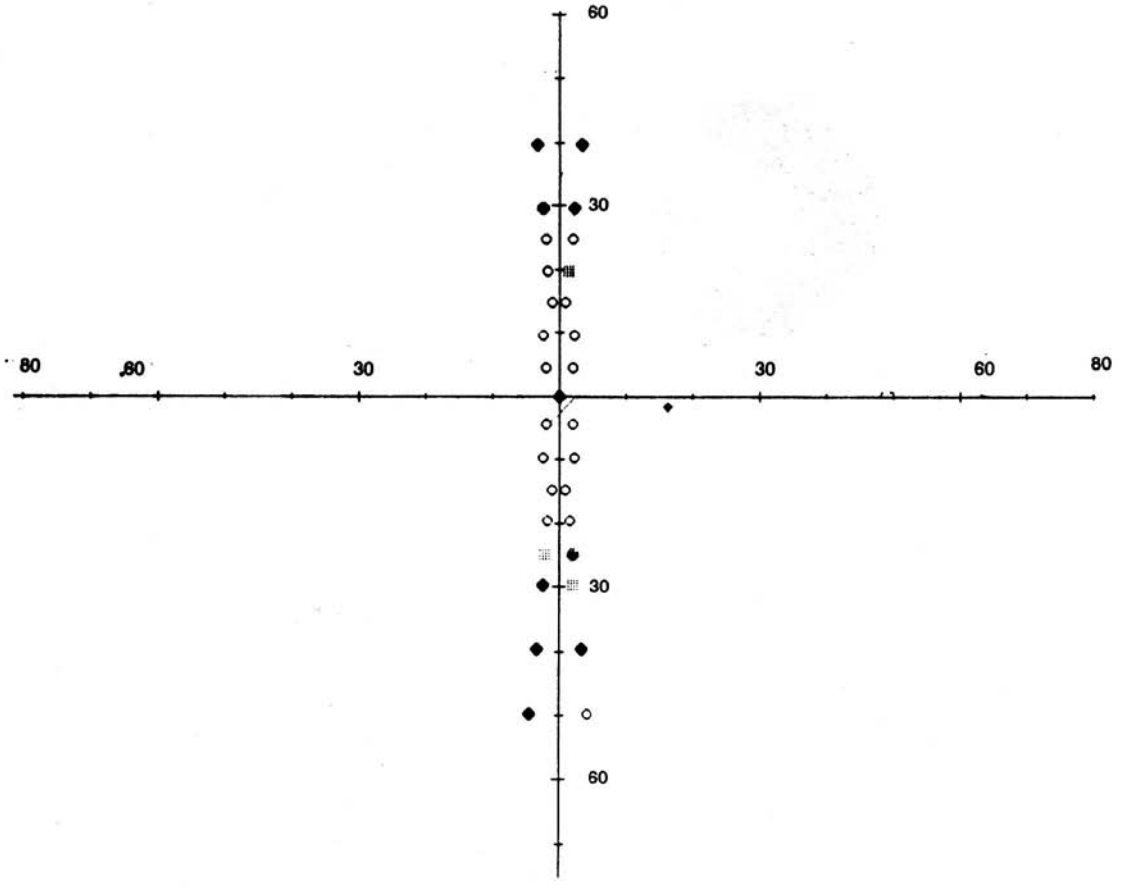


Fig. 6.37J: Isopter + threshold (right)

DATE	04-17-1993	TOTAL POINTS	31	BACKGROUND	31.5Asb
TIME	16:11	MISSED POINTS	8	STIMULUS	35 dB
ID		FIXATION LEVEL	3	DURATION	0.2 sec
NAME		FALSE POSITIVE ERRORS	0/ 2	INTERVAL	NORMAL
AGE	years old	FALSE NEGATIVE ERRORS	1/ 1	TARGET	CENTER
VISION	( )	ELAPSED TIME	2 min 33 sec	STIMULUS COLOUR	WHITE
CORRECTION	none	A			
				STIMULUS SIZE	III



NORMAL	LEVEL I	LEVEL 2	MISSED POINTS
STIMULUS	28dB	23dB	0dB

Fig. 6.37K: Screening — V. meridian (quick) (right)

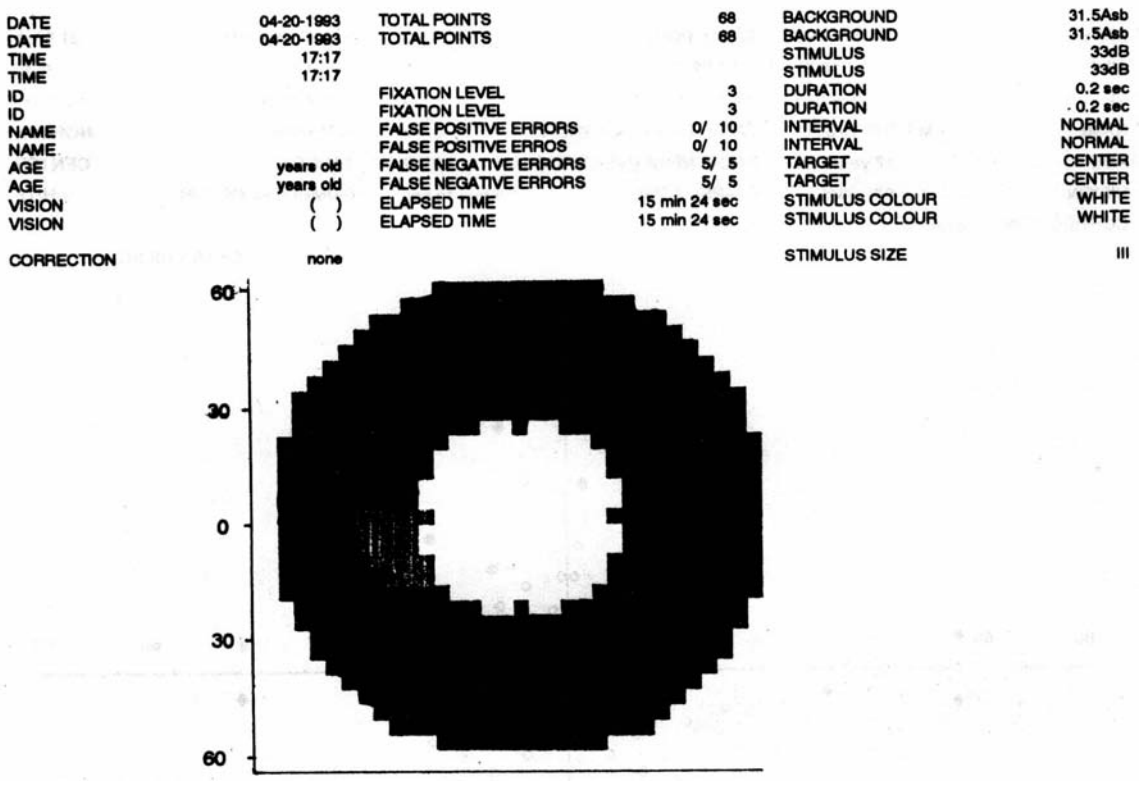


Fig. 6.37L: Threshold — perimeter (right)

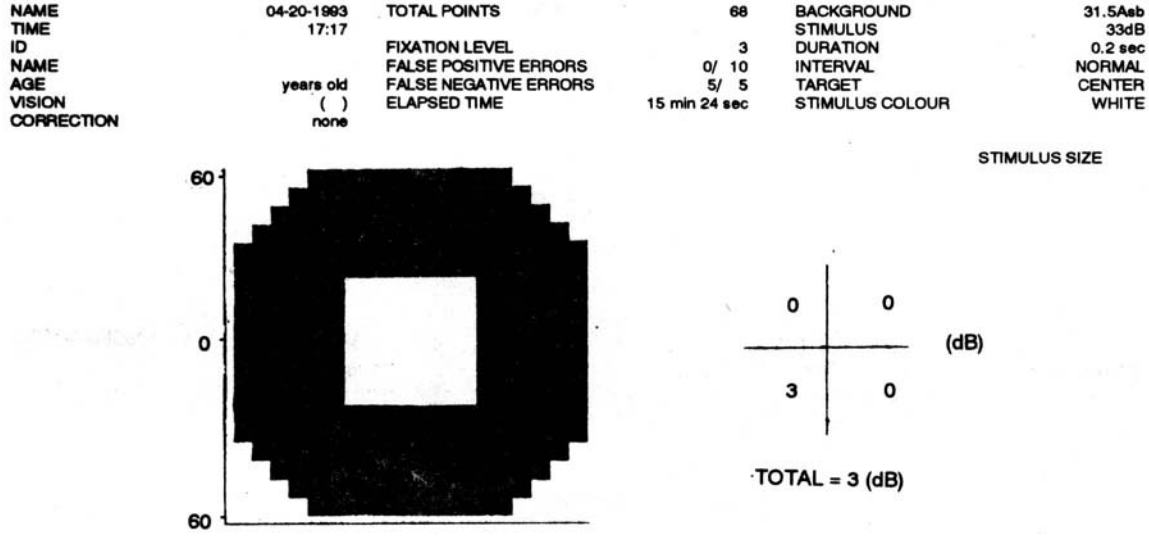


Fig. 6.37M: Threshold — perimeter (right)

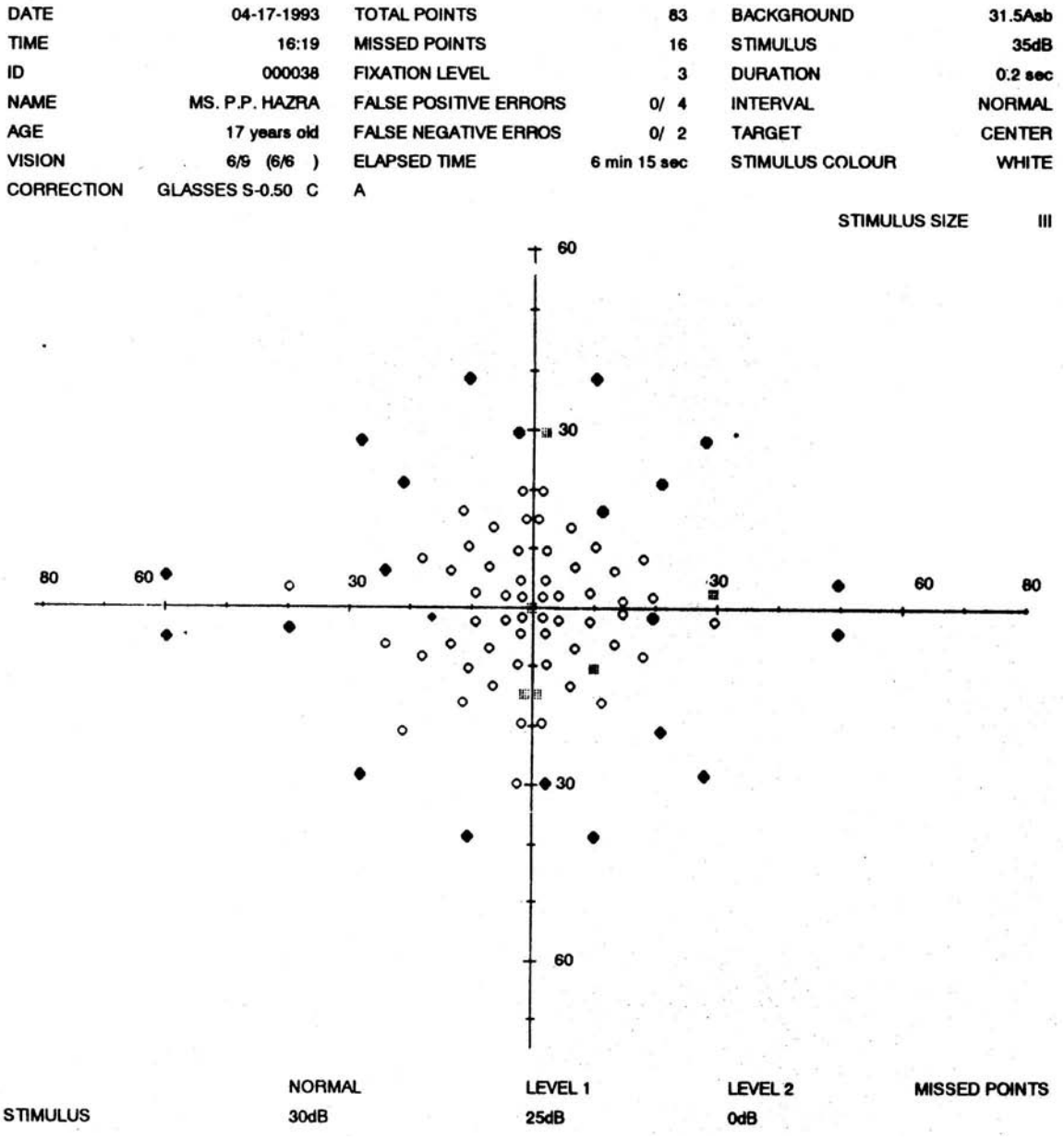


Fig. 6.37N: Screening — standard (left)

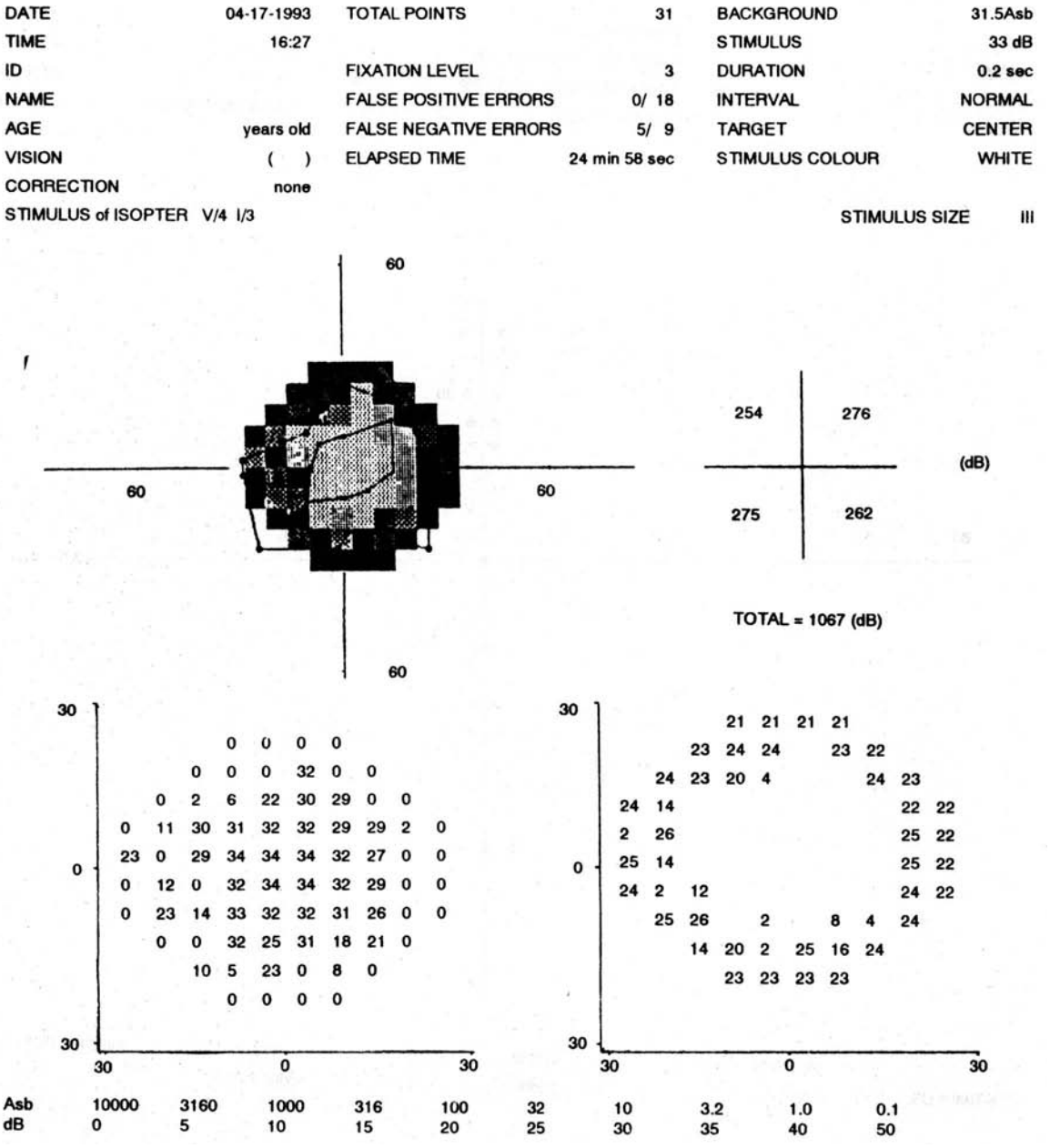
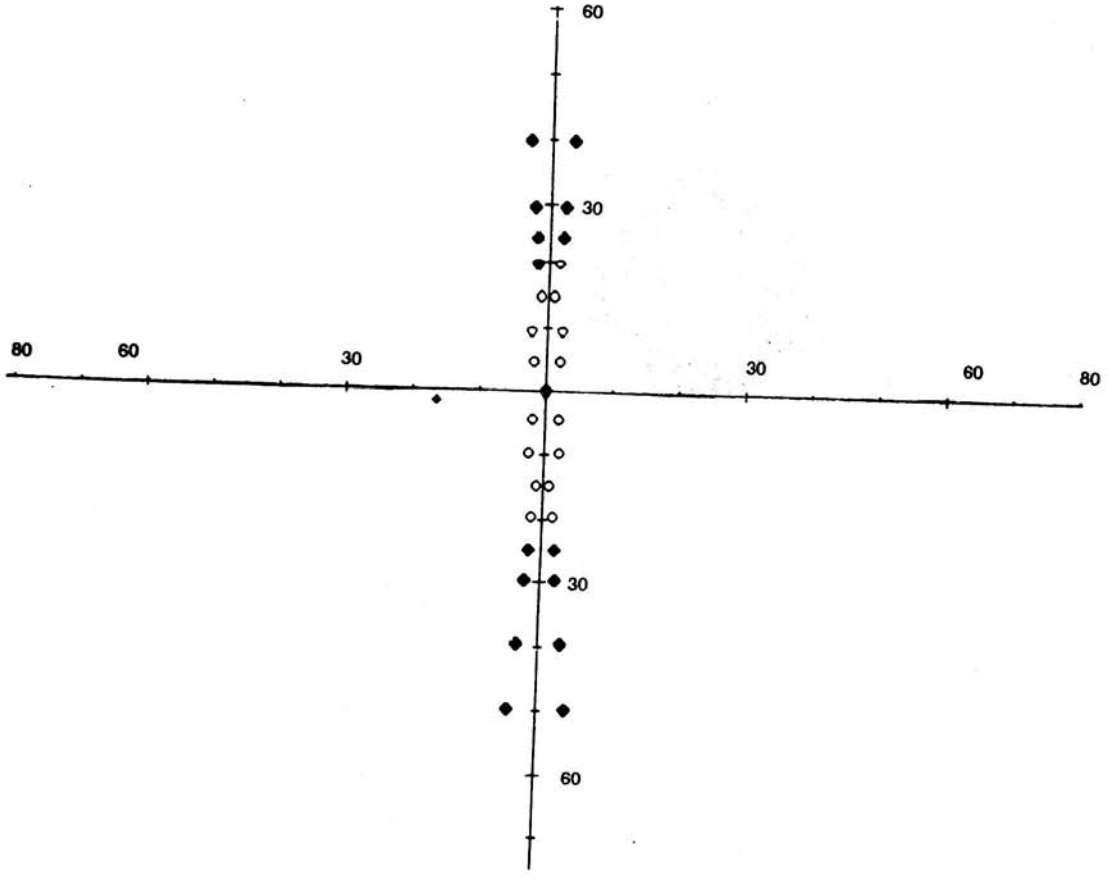


Fig. 6.37O: Isopter + threshold (left)

				STIMULUS	33dB
ID		FIXATION LEVEL	3	DURATION	0.2 sec
NAME		FALSE POSITIVE ERRORS	0/ 2	INTERVAL	NORMAL
AGE	years old	FALSE NEGATIVE ERRORS	0/ 1	TARGET	CENTER
VISION	( )	ELAPSED TIME	2 min 47 sec	STIMULUS COLOUR	WHITE

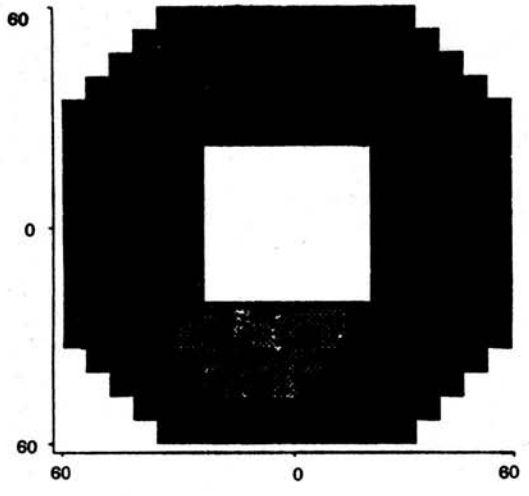


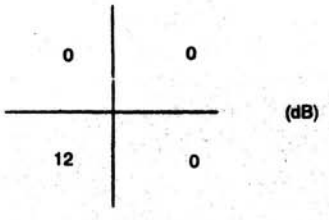
	NORMAL	LEVEL 1	LEVEL 2	MISSED POINTS
STIMULUS	28dB	23dB	0dB	

Fig. 6.37P: Screening—V. meridian (left)

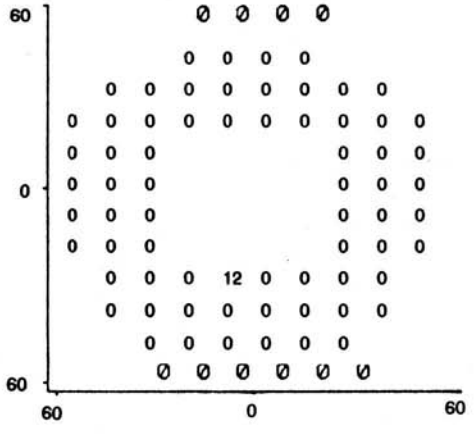
DATE	04-20-1993	TOTAL POINTS	68	BACKGROUND	31.5Asb
TIME	17:58			STIMULUS	33dB
!D		FIXATION LEVEL	3	DURATION	0.2 sec
NAME		FALSE POSITIVE ERRORS	0/ 10	INTERVAL	NORMAL
AGE	years old	FALSE NEGATIVE ERRORS	6/ 6	TARGET	CENTER
VISION	( )	ELAPSED TIME	15 min 26 sec	STIMULUS COLOUR	WHITE
CORRECTION	none				

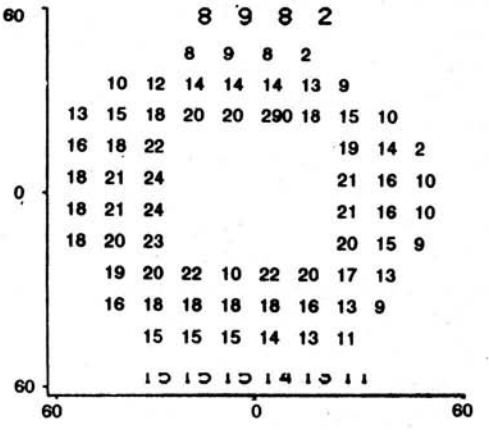
STIMULUS SIZE III





TOTAL = 12 (dB)





Asb	10000	3160	1000	316	100	32	10	3.2	1.0	0.1
dB	0	5	10	15	20	25	30	35	40	50

Fig. 6.37Q: Threshold — perimeter (left)

number setting by one notch. This prevents a stimulus jump of 0.5 log units, which may be supra-threshold for the tested receptor site. When the I_4e lever setting is reached, the upper left levers are slided to I_a and the bar lever is changed to the open position.

6. When the foveal threshold is found the level of sensitivity at 0^o is marked using the intensity ruler.

Testing the eccentricities It requires the following steps:

1. For testing the rest of the hill of vision profile the plexiglass plate is shifted to the left hole. Four fixation dots are shut off and the patient is instructed to look at the fixation port for the remaining part of the test.
2. With the chart holder adjusted to the correct meridian, the intensity ruler is moved slowly from zero in 1 to 3 degree steps. The ruler must be moved every 3^o to 5^o to measure normal areas and every 1^o to 2^o across scotomas.
3. It must be started from the infrathreshold, if the first presentation of stimulus is seen, the intensity of the target is decreased by 0.4 log units, i.e. drop from the "d" to "a" and must be proceeded again. The target must be presented for a 0.5 second period and the patient is instructed to respond when he or she looks the target. The profile must be mapped continuously adjusting the levers in 0.1 (alphabet letter) log unit steps.
4. When blind spot is reached, 15^o temporal to fixation, no target will be seen. The actual edges of the blind spot must be ascertained by shifting 3^o to each side of the 15^o point to find the rim. The intensity is increased until threshold for the rim is elicited.
5. Similar technique is used to map the extent of scotomas for their rim and depth. The scotoma must be tested with an infrathreshold stimuli similar to the threshold stimulus elicited at the rim of the depression. Until each point is evaluated for the actual defect depth the stimulus must be moved across the diameter of the scotoma in 2 shifts increasing or decreasing the stimulus intensity.
6. The lens must be removed when testing any point 20^o from fixation.
7. The rest of the meridian is examined. Usually only the areas where scotomas or constrictions occur in the meridian are tested.
8. Documentation of the static field is done. The slope of point for that meridian is drawn on the chart. Following items are recorded—background luminosity (usually 31.5 asbs), visual acuity and lens for distance, date, correction used to test at near, pupil size, target size (usually I), meridian tested and foveal intensity threshold in the lever of sensitivity at 0^o.

GOLDMANN BOWL PERIMETER — KINETIC PERIMETRY

Instruments

1. The bowl perimeter should be placed in a dark room.
2. The machine's bulb must be calibrated each day and the background reflectance must be adjusted while each patient sits in front of the bowl.

Patient's Preparation

1. Patch the other eye with an opaque white patch to maintain light adaptation in the covered eye.
2. The patient's head must be positioned in the head-rest and the head strap is secured. The chinrest is adjusted so that the examined eye is centred in the viewing telescope.
3. The small lever at the bottom of the observers viewing tube adjusts a mirror in the central fixation port. The mirror in the tube is flashed to make the patient understand where to maintain fixation.
4. Patient must be explained about the test and instructed to use the buzzer when he or she looks the target.
5. The appropriate near lens combination must be calculated when testing the central 30^o. The lenses with thin wire rims are preferred as they will not artificially, constrict the inner isopter. The lens must not be positioned in front of the eye until outer isopters, are tested. Aphakes and high hyperopes will have

compressed fields and blind spots displaced closer than normal. High myopes will have expanded fields and blind spots outside the 15° eccentricity.

6. The recording chart is positioned in the holder with vertical meridian in the centre notch. The side clamps are tightened so that the paper will not move.
7. The pupillary width is measured in the telescope on the millimetre scale. Pupil must be dilated if it is less than 3 mm wide.
8. Artificial contraction of peripheral isopters must be prevented by taping up drooping eyelids, moving all hair off the face or repositioning the patients head when anatomical obstructions occur. Antifactual constriction is suspected when peripheral isopters overlap in the constricted area for which no suspected defect is anticipated. The common areas or artefacts occur in the superior or inferior nasal fields.

Techniques

1. Find the threshold stimulus at a point 50 degrees temporal to fixation on the horizontal meridian. To start with I_2e is used. If I_2e fails, the stimulus is increased to I_3e, I_4e, II_4e, III_4e, IV_4e, and V_4e, until the target is appreciated. The Roman numerals and Arabic number levers are the most commonly employed. The other two filter levers are kept to the far right. Usually for patients with normal fields the peripheral isopters target is I_3e, or I_4e. There is some normal shrinkage of the peripheral isopters as one ages.
2. Using the threshold target, the outer isopter is marked at each 30° meridian starting at the 75° meridian. Then the target should move along the meridian from non-seeing to seeing areas at a speed of 5° a second until the patient sees the target, then this point should be marked on the recording chart. The target should be continued to rotate around the circumference of the field until all quadrants are examined. The target should be moved at right angles to the boundary of the isopter. It is advisable not to map directly on the vertical 90° or nasal horizontal 180° meridian. Instead stimuli should be presented kinetically 5° to each side of raphe. This eliminates error in documenting sloping borders as steps. When true steps are suspected, to confirm the defect the stimuli should be moved perpendicular to the border or static presentations should be done on each side of the depressed isopter.
3. In areas where there is constriction, the defect should be quantitated with a larger and smaller size target. Isolated scotomas should be looked for by performing static with the larger isopter's target.

How to Test the Central Zone?

1. Required near lens is placed in front of the eyes as close as possible.
2. The threshold for 25° temporal to fixation to be found to start with I_1e, should be used and the targets should be increased from I_1e to I_2e, I_3e, etc. until the threshold target is determined.
3. The central isopter should be marked by moving kinetically on every 30° meridian. If the isopter seems constricted temporally by the lens rim, the lens should be removed and the test should be repeated in this region.
4. The central threshold target should be moved along the meridian towards fixation, to map the blind spot or evaluate the inner isopter for scotomas. The patient is asked to respond when the target disappears. Mapping should be started in the centre of a known defect and should be continued in the eight cardinal directions, where scotomas are known to exist.
5. Blind spot can be located by starting at 15° temporal to fixation and 1.5° below the horizontal meridian, where the target will disappear. Target should be moved out in the eight cardinal directions to map the blind spot borders.

6. Scotomas may be elicited by using static at the region of the central co-ordinates. A scotoma may exist if 3 points are missed in a row. Size and shape of any scotoma can be marked by moving out from the centre of the area until the target is seen.
7. When either an isopter constriction or scotoma depression is found, two more targets are used to quantitate the defect.
8. The fixation spot in the bowl is 2^o wide. Central scotomas more than 2^o can be mapped kinetically by moving out from fixation, until the stimulus is visible.
9. Paracentral defects in the 2.5^o eccentricity can be mapped with static in the four quardrants and at each of the eight major meridians.
10. Rest of the central field is checked by doing static at the junctions of each meridian and eccentricity at 5^o, 10^o, and 15^o. The stimuli must not be presented in rhythm.
11. Fixation must be checked throughout the test. If there is any problem in maintaining fixation the mirror in the fixation port must be flashed. When fixation losses are frequent the effect of nystagmus or large central scotomas must be ruled out.
12. Intermediate filter target (i.e. I_3e) should be used to evaluate isopters more than 15^o apart in the periphery or 10^o apart in the central field.
13. The excursion arrows at the bottom of the chart must be followed to move the recording stylus arm from one side to another.
14. No charting can be performed in the projection ports from 70^o to 90^o horizontally in the bowl.

Charting and Documentation

1. The name, date, diagnosis, vision, pupil size, refraction and near addition used for the central 30^o must be written on the chart. In the field chart right border comment on the quality of the patients fixation ability, co-operation and validity of response.
2. A standard colour coding of stimulus size and intensity should be co-ordinated with the documentation of the field and the relative intensity grid at the right lower corner of the chart.
3. Areas with scotomas should be tested for their depth by recording the stimulus value that it perceived at the centre of the defect.
4. Cross hatch areas of scatter or "in and out" perception. The stimulus value found to produce scatter is noted.
5. An isolated scotoma should be tested between the isopters. If not found, it must be indicated on the chart and the target size used should be noted.

AUTOMATED PERIMETRY—BLENDING OF SCIENTIFIC EXCELLENCE AND ARTISTIC SPONTANEITY

Introduction: Why Test the Visual Field?

The visual field is all the space in 3-dimension that one eye can see at any given instance with real-time measurement, thus it represents areas of relative retinal sensitivity. Such a structure was romantically termed as the "Island of vision in a sea of blindness" by Traquair, who expanded the original idea of Euclid and Heliodorus and described the variable slopes of this island (Fig. 6.38).

Visual fields are important because the pattern of deviation from their usual egg-shaped lines may localise the cause of defect of neurovascular tissue in a long journey from eye to brain, help determine the activity and prognosis of neuro-ophthalmic diseases, suggest management of endocrine disorders, unexplained headache, vascular diseases, etc. The prime value of a visual field to an ophthalmologist is its ability to indicate the progression or regression of a disease process. This can serve as the basis for changes in treatment or reassurance that the current therapy is effective.

Analysis of Visual Field

It is done by perimetric methods. Perimetry means monocular measurement of the periphery of the visual field, where the nonoccluded eye must

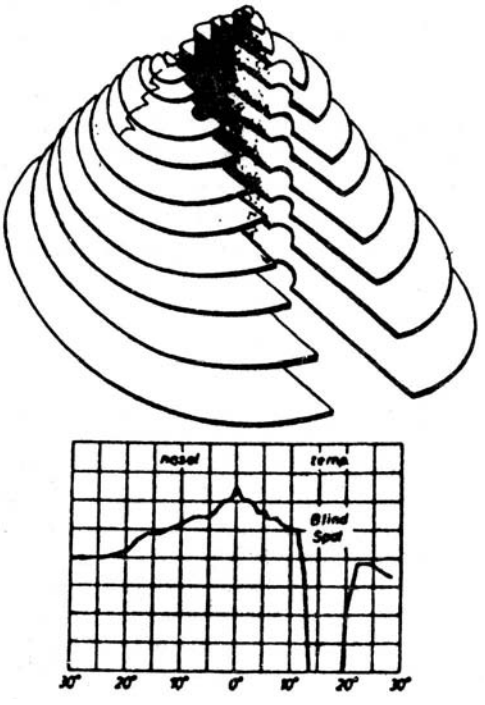


Fig. 6.38: Traquair's hill of vision. If pieces of plywood are cut in the shapes of isopters from one visual field and stacked in appropriate positions on top of one another, a view of the resultant model of a hill island will appear same as the visual field. A view of the island in profile, or better, of a vertical slice through the centre, will appear similar to the light-sense test results, that were demonstrated in the figure thus, the hill or island of vision may be sectioned horizontally and visualized from the side as profiles

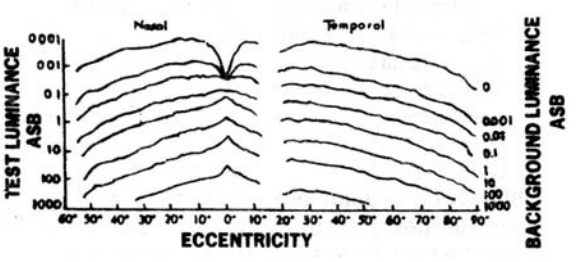


Fig. 6.39: Aulhorn's curves of average static perimetric light sense lie along a horizontal line through the point of fixation and the normal blind spot of the right eye. The luminances or intensities of the background light in each of eight adaptation states are respectively indicated in apostilbs (ASB) by the numbers along the right side. The intensity of additional light projected onto the background is on the ordinate scale on the left

remain stationary by looking steadily at a preselected target. Thus, variable relative retinal sensitivity, as a function of visual acuity and eccentricity in degrees from fixation, is demonstrated, according to Osterberg's curve of cone distribution (Fig. 6.39).

Conceptual Differences in Test Method — Kinetic Versus Static

When visual field testings are performed on perimeters or campimeters (testing on a flat tangent screen) with test objects that move back and forth between nonseeing areas and zones in which they are detected, the technique is termed 'kinetic' as opposed to stationary testing, which is 'static'. In 'kinetic' testing, one attempts to find in, the visual field locations, that are barely sensitive to preselected test objects. In 'static' testing, one attempts to find in the visual field sensitivity of the eye at preselected locations.

Kinetic Versus Static Testing: Ideal Relationship

A. In co-operative patients, static perimetry is generally more accurate in measuring the depth, slope and extent of any demonstrated defect; while kinetic perimetry has the advantages of speed of testing, comprehensive coverage of the entire field, and production of recognisible isopter pattern.
B. Flat-shaped/sloped defects are much more difficult to map kinetically than statically.
C. The delineation of scotomas within the fields is easier by static method, but isopter patterns that show, among their other values, where to test for scotomas, are easily produced during kinetic testing, and are practically impossible to obtain with static testing.
D. But for sharp, meaningful and non-scattered production of isopters, the direction of movement of kinetic test objects should ideally be perpendicular to the expected isopter, and speed of the test object should be regulated

for precise knowledge regarding the effects of temporal and spatial summation, which is very difficult to control in kinetic testing. Newer APs with computer assisted isopter protocol solves this.

ALTERNATIVE METHODS OF PERIMETRY

Until advent of automated perimetry, projection perimeter designed by Goldmann (1940) overcame the inconsistencies of the tangent screen. The hemispherical bowl provides an uniform background illumination that can be easily calibrated and will remain constant between examinations. It places all test areas equidistant from the eye creating an ideal testing condition; projection of test object allows the target to be turned 'on' or 'off', a concept useful in 'kinetic' perimetry and vital to 'static' perimetry. Also the stimulus can be varied in both size and brightness, bearing an inverse relation of 3.15:4, but better expressed by 0.5:0.6 log units. Also, single bulb that provides both stimulus presentation and background illumination nullifies age-related diminution of bulb luminescence. Thus, Goldmann perimetery allows accurate, precise, and quantifiable documentation of a patient's field of vision and demonstration of the size and depth of any scotomas, identified. It overcomes major disadvantage of manual field analysis, where fixation cannot be monitored and quantification of field loss is relatively imprecise. But, the technique of performing visual field testing by Goldmann always remains an art, difficult to learn. Also, the experience, patience, procedure-induced errors and longer testing time are additive limiting factors in its usefulness.

AUTOMATED PERIMETRY (AP): BEGINNING OF A NEW ERA

APs represent a departure in thinking and technique from classical methods. It is suitably sensitive to detect pathology early, and accurately; as well as specific enough not to falsely identify normals as 'glaucomatous' (Fig. 6.40).

Advantages

Optimisation and standardisation of the testing protocol In AP the skill, art and technical expertise to perform perimetry is contained within the

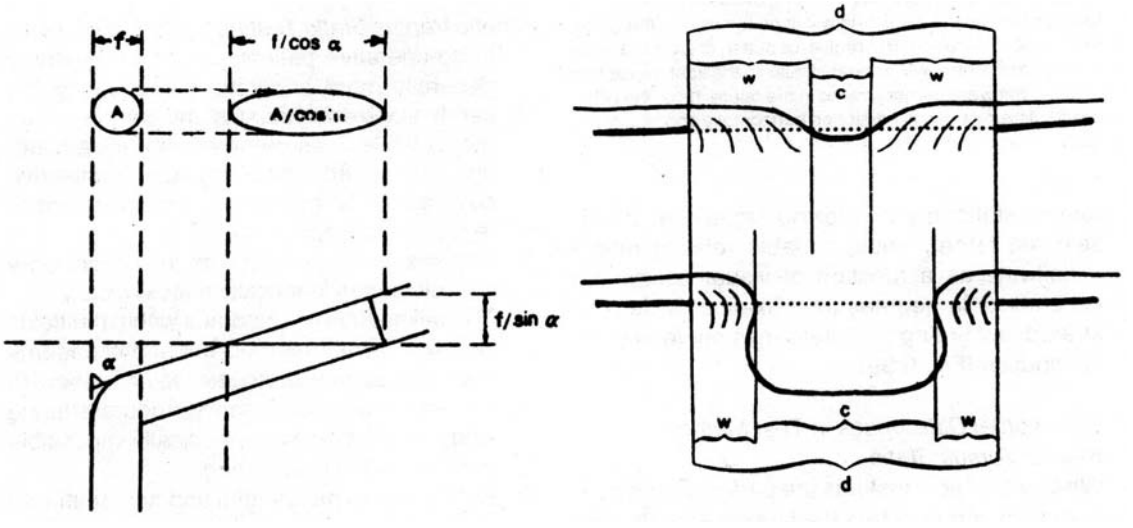


Fig. 6.40: Skeleton drawing of nerve fibre with oblique course at level of scleral lip. Contribution A/cos a of nerve fibre to rim area increases when deviation increases. It indicates fibre thickness: deviation from perpendicular course; and A, cross section. Schematic sections of two optic discs with same diameter. Top — shallow cup, oblique fibre course, and large rim width. Bottom — deep cup, perpendicular fibre course, and small rim width C indicates cup diameter; d, disc diameter; and w, rim width

computer software. Thus it produces standardisation by eliminating the perimetrist, and ensuring self-calibration.

Improved sensitivity, accuracy, quantification, reproducibility, and repeatability in the detection of field loss Accuracy of detection of field loss is ensured by performing static threshold/supra-threshold estimation of retinal sensitivity with randomised stimulus presentation and optimal stimulus duration. Quantification of defective depth for each test location in numerical value and/or gray scale pattern on a thermal hard copy printout, has opened a variety of new avenues for data analysis and comparison. Moreover, these values allow very precise retrospective analysis of serial field examination results, to assess whether there has been any change over time.

Objective assessment of the patient's performance Random presentation of stimuli overcomes the patient's tendency to predict the appearance of the next stimulus. Further standardisation is achieved by fixing duration of the stimulus presentation to 0.2 sec, which is regarded as optimal for physiological summation of retinal stimuli to occur without permitting the involuntary eye-movements. Also, in AP, fixation is monitored independently of the technician by occasionally presenting a stimulus in the predetermined area of the patient's blind spot. In addition, a video monitor allows the technician to ensure that eye is centrally placed behind the trial lens, and this position is maintained throughout the test. Some of the latest AP have additional fixation monitoring with infrared system, like KOWA AP 3000.

Easy interpretation and statistical analysis of test results Progression of a disease process, clinical study of perimetric maps, and different regression analysis can be done easily.

Disadvantages

A. Despite standardisation, the response errors and variability exhibited by patients, impose limitations on the accuracy and reproducibility of AP test results. These variabilities are of three types:
   1. *Patient factor* Refractive error, pupil size, degree of media clarity.
   2. *Testing factor* Relative size and intensity of the stimulus, the time interval between successive stimuli (e.g, 2 dB or 4 dB) no. of reversals for a decision.
   3. *Psychophysical factor* The state of light adaptation, receptor fatigue, and the width of the zone of uncertainty.

B. While the detection programmes are quick, the quantitative central 30^{o} protocol is time consuming, and takes an average of 15-18 minutes. With printout and additional information regarding the periphery, increases it up to 40-45 minutes. This is considerably longer than the average time to plot Goldmann's field manually.

C. APs are less valuable in patient's with very advanced field loss, as there may be only handful of stimulus, responded by the patient. This is very discouraging to the patient, who is only able to respond to as few as one stimulus presentation of 50. It greatly limits the ability to detect any change in the visual field.

D. Reliability markers are falsely indicated in patient's with advanced field loss.

Basic Working of an Automated Perimeter

APs adopted many of the design features of the Goldmann perimetry, adding a computer to perform the examination itself. Most use a hemispherical bowl, similar stimulus sizes and similar level of background illumination. Automated protocols rely on the technique of static perimetry, determining the dimmest light that can be detected in 50 per cent of trial presentation. This "threshold" value is determined at about 70 locations in the field of vision, and is reported on a hard copy thermal printout. Values are accompanied by a 'gray' scale picture, a computer interpolation of the 70 test locations in 'threshold' strategic locations, and areas in-between, for which additional estimated values are calculated by the computer—thus a smooth and soft textured gray scale picture is obtained.

The Interior of an Automated Perimeter— How Does it Function?

For proper understanding of an automated perimetre, its basic anatomy and physiology must be

sought for; that is its structure, function and their interrelationship. Chiefly, these are as follows (Fig. 6.41, Plate 13).

1. *Stimulus presentation* With generations passed, multiple techniques have been described. It originated with random spot presentation on a TV screen — later replaced by a grid of light emitting diodes on a screen. These LEDs were driven by a high frequency pulse current of a variable duty cycle (it is the ratio of the duration of a pulsed current to the total time from the leading edge of one pulse to the leading edge of the next) — thereby permitting variable brightness to be achieved at each spot. But, today best quality APs use projection devices. Projection offers the advantages of an easily calibrated light source, the ability to utilise various colours of the stimuli; the ability to control the size and brightness independently of one another, and the ability to position the spot anywhere on the screen, thereby allowing theoretically, the possibility of both 'kinetic' and 'static' perimetry. In projection perimeters following principles are adopted, regarding presentation of test objects:
   i. At random presentation to eliminate patient's anticipation.
   ii. Standardised time interval of 0.2 sec between stimulus; with age-correction if necessary, where interval could be prolonged in appropriate cases.
   iii. Movement of test object will be always from 'non-seeing' to 'seeing' area.
   iv. Intermittent presentation of the test object in the 'seeing' areas to alleviate the patient's anxiety and apprehension.
   v. Test objects should be just above 'threshold', for the locations being screened.
   vi. Supra-threshold static targets should be presented at a consistent duration of time, usually half a second to one second.
   vii. Kinetic targets for isopter testing should move at a rate of 5 degrees per second in the periphery, and a bit slower in the central field.

2. *Background illumination* Apostilb is an unit of measurement of luminance, the reflected 'brightness' of light from a surface. The human eye is sensitive to light over an enormous range of intensities, varying approximately one billion times (10^{-5} to 10^{5} Asb). Differences in light intensities are physiologically interpreted on a relative scale, not in an absolute or linear fashion. This means, the eye needs about 10 per cent change in 'brightness' to discern a difference between lights. At a background level of 0.1 Asb, the eye could detect a light, that was .01 Asb brighter — while at a brighter background of 1000 Asb, it would require a light that was 100 Asb brigher to detect a difference. Weber, in 1850 hypothesised that, gradations of stimulus are discriminated proportional to the log of the stimulus strength. Logarithmic units (decibels) follow Weber's law and also compress the billion-fold eye sensitivity range into workable numbers. One bel represents one log unit, while a decibel represents one tenth of a log unit. The Octopus perimeter assigns its brightest stimulus 1000 Asb with the value of 0 dB, with each decibel representing a 0.1 log unit decrease in the intensity. The Humphrey automated field analyser uses a different background illumination (31.5 Asb vs 4 Asb in Octopus) and corresponding different stimulus intensities, the brightest stimulus being 10,000 Asb. Despite different values, the contrast between the stimulus and background illumination is fairly constant, as given by:

$$\frac{\text{Delta L}}{\text{L}} : \frac{*1{,}000}{4} \text{ versus } \frac{*10{,}000}{31.5}$$

The most important thing to keep in mind is to make background illumination constant and reproducible in different protocols.

3. *Responsive drive* Initially to start with, in older APs, the option was a simple 'yes' or 'no' response, typified by a pushbutton. However, psychophysical literature puts emphasis on 'forced choice device' to ensure accuracy. Joy-stick was used at first, soon replaced by

"temporal forced device", which consists of presenting a stimuli in one of three (or more) time intervals, and requiring the subject to choose, in which of the three time intervals he saw the stimulus. However, modern APs use video monitored trigger type response device. Latest in the technology is the design of a computer assisted pupil guided response device, in which a computer will monitor the patient's pupil, and decide whether or not the spot was in fact 'seen'.

4. *Fixation monitoring* Assessment of the reliability of the patient is achieved by monitoring the patient's fixation performance throughout the test, assisted by a video monitor, described by Heijl and Krakau. Good fixation is adequately stimulated by the use of frequent, supra-threshold, randomly appearing test spots in the predetermined area of patient's blind spot. Octopus uses the first, while Humphery uses both the techniques for fixation steadiness. Kowa, in addition, has developed its indigenous way of fixation monitoring by transpupillary five grid infrared optical detector. Newer developments are coming, where test spots can be moved spontaneously to compensate for any small deviation from fixation, in such fashion that the retinal image of the test spot remains stationary, despite eye movements.

5. *Method of approaching threshold* The basic principle of perimetry is to obtain a measurement of the eye's indirect vision by determining the peripheral limits of vision and the retinal sensitivity (its ability to discriminate different light intensities) within those limits. Thus, essentially, it is a mapping of 'hill of vision'. The lowest level of illumination that can be perceived at the retina is termed the 'retinal threshold' for that point. Below this value, a stimulus is too dim to be perceived (infra-threshold) and more intense (brighter) the stimulus than threshold, the easier such a stimulus should be seen — supra-threshold). The higher the retinal threshold, the more sensitive are the retinal receptors at that point, and the dimmer the stimuli which may be perceived.

   Methods for approaching threshold are of three types: (a) method of ascending limits; (b) single stair case method; (c) double stair case method.

The technique for seeking a threshold, in the psychophysical literature, is known as the method of ascending limits. That is, a stimulus starts infra-threshold and is progressively increased in one step increment, until it is just perceived, at which point the perceived stimulus is considered to be "threshold" — the test usually terminates at that point, and attention is turned to the next point. However, bowl APs like Octopus/Humphrey/ Kowa, etc. perform static threshold testing by stair case method, where retinal sensitivity is assessed at multiple predetermined points, the location being dependent on the particular programme selected.

The age-matched brightness of the projected spot is decreased by successive attenuation process, with the help of neutral density filters in 4 dB step (0.4 of a long unit), until the stimulus is too dim to be perceived visually. The illumination of the spot is then increased in 2 dB steps, until the patient responds to the stimulus. The illumination is then again decreased, and successively increased to 'fine-tune' the stimulus and obtain a precise threshold measurement — the 4-2 single staircase, or 4-2-2 double staircase programme. This allows an exceptionally precise and accurate determination of the retinal threshold of seeing over each tested point on the 'hill of vision'. In general, the distance between tested points in APs is 6 degrees, and this has been shown to maintain the best balance between the sensitivity of the test, and the time necessary to conduct the test.

Measuring threshold The ratio of two powers in a mechanical system is expressed in logarithmic units, called 'decibles'. The intensity of light is measured in 'apostilb'. However, as visual perception seems to relate to the ratio between light intensities rather than to the difference between them, the attenuation of light is measured in logarithmic units decibels. Thus, the retinal

sensitivity is expressed in decibel. The light of a bowl perimeter projected spot is attenuated by the neutral density filters, measure in log units (decibel) — with one log unit corresponding to 10 dBs. If a point on the retina is found to respond to light of intensity reduced to one-tenth of its value, by a one log unit filter (10 db) and no dimmer than that, then the retinal threshold of that point is 10 db. A 2 log unit filter reduces the light intensity to one-hundredth of its original value, resulting in retinal sensitivity of 20 dB. A 3 log unit filter reduces the brightness by one-thousandth of its original value, achieving a retinal sensitivity of 30 dB at threshold. Thus, the greater the attenuation of light, the dimmer the stimulus, the higher the retinal threshold sensitivity.

Strategies Adopted in Clinical Practice

Threshold static perimetry Minimum (threshold related) luminance necessary for the patient to just detect the presence of the target — the size, colour, location of it remaining constant at real-time measurement.

Supra-threshold static perimetry Prerequisites remaining same to threshold type—only the luminance value of the target is adjusted just above the threshold value.

Threshold related suprathreshold static perimetry Here, the target luminance value is adjusted at a level, slightly greater than the expected sensitivity gradient of the visual field. Thus it is helpful in analysing serial field reports.

Section designed, profile static perimetry Computer-assisted rapid section of the visual field is done through X-Y-Z decoupling; then meridional threshold sensitivity is estimated at 5 degrees interval, along 45-225, 135-315 degrees, etc. The datas are plotted in a graphic pattern.

Customised, circular threshold perimetry Here, the threshold sensitivity of the central field is measured along concentric circles of 5, 10, 15, 20, 30 degrees. Values are plotted graphically to show the 'decay curve'. It is extremely useful in linear regression analysis of serial fields.

GENERATIONS OF AUTOMATED PERIMETERS

First generation This includes rapid visual screening devices, like:

1. Harrington-Flocks screener with flash presentation of multiple dot patterns.
2. Friedman's visual field analyser with static presentation of single/multiple test objects;
3. Lynn and Tate's on-screen display presentor.

Second generation This include Competer,/ Dicon 2000,/Synemed field master 101 PR,/ Squid autoperimeter 300,/Perimat or Peritest 206, etc.

Third generation Fully automatic with technical novelty and extended computer software capabilities. These are Octopus/Humphrey visual field analyser/Kowa.

TECHNICAL DETAILS

Octopus

Developed by Frank-Mauser (Interzeag AC, Schlieren, Switzerland). Available models are 201R, 2000 and 500E — the differences lies in the capability of the computer for data processing and analysis (Table 6.2). Two units are operating—perimetric and control.

The control unit has a computer-guided printer for hard copy printout of the datas, which are expressed as : (1) gray scale pattern, (2) symbol presentation, (3) numeric values, (4) display of deviation and measurement of defect depth, by comparing with age-matched normal values, (5) qualitative changes in serial field testing with delta programme.

Programmes Available

Basic programme Full field P 23, central field P 31, 33, 34, mid-peripheral field P43, special GI protocol P 30 quantitative thres-hold estimation P 03/23, 31, 33, 34, 43.

Upgraded programmes High density programme P 11 and P 61 with only 3 degrees separation along X-Y axis.

Advantages

(1) Rapid automated screening; (2) standardised differential light threshold; (3) good central fixation

Table 6.2: Octopus perimeter models

Perimeter type	*Cupola diameter*	*Fixation distance*	*Stimulus size*	*Stimulus intensity*	*Background luminance*	*Fixation monitor*
a. 201R	100 cm	42.5 cm	Goldmann 0-V	.002-1000 Asb	4 Asb	Infrared TV monitor
b. 2000	85 cm	35.7 cm	Goldmann III & V	-do	-do-	Electronic
c. 500E	-do-	-do-	Goldman III	-do-	-do-	Telescope

monitor; (4) estimation of MD, SF, CLV; (5) multiple level qualitative/quantitative screening; (6) peripheral field strategy; (7) computer-assisted data base management system for storing, retrieving, modifying, deleting, marking, and comparing of test results and age-matched normal values.

HUMPHREY VISUAL FIELD ANALYSER

Fully automatic projection perimeter, devised by Allergan Medical Corporation, San Seandro, California, Models available are H610, H620, H630.

Technical data Cupola diameter 660 mm, background illumination 31.5 Asb, stimulus intensity 0.08-10,000 Asb, stimulus size Goldmann I-V with colour modulation, fixation monitoring, video-assisted direct monitor, and random electronic blind-spot check, computer software, light pen and mouse-drive system.

Advantages (1) Clinical usefulness is promoted by eccentricity compensated, threshold related protocol, which makes accurate quantification, and space adaptive screening possible. (2) Both standardised and customised static threshold/ suprathreshold related protocols. (3) Specific glaucoma screening programme. (4) Complete range of stimulus size, brightness, and colour. (5) Statpac software in H620 and H630 models for statistical analysis and possible probability maps.

Kowa

Fully automatic projection perimeter, devised by Kowa Corporation, Japan. Models available are AP 200, AP 340 and AP 3000.

Technical data Cupola diameter 660 mm, background illumination 31.5 Asb, stimulus intensity 0.10-10,000 Asb, stimulus size, Goldmann 0-V with colour modulation, fixation monitoring, on-screen displayed direct monitor, random supra-threshold, blind-spot check, and Kowa infrared transpupillary modula for with a buzzer.

Available progammes Screening standard, precision, vertical meridian, glaucoma centre, periphery (standard and quick), threshold protocol of centre, periphery, macula, with isopter etc.; supra-threshold protocol of centre, periphery, macula, blind-spot, isopter screening, custom, circle and meridian progamme, quadrantic threshold programme single/multiple quadrant.

Advantages (1) All advantages of Humphrey; (2) easy to interpret, (3) special computer—assisted isopter protocol to perform kinetic perimetry with artistic excellence, (4) accurate measurement of defect-depth, and probability charting.

SCREENING SCHEDULE OF AN AUTOMATED PERIMETER

A. Initial screening of the patient requires visual acuity measurement, anterior segment, slit lamp biomicroscopic examination, pupillary function, clarity of media; thorough fundus examination, optic disc and nerve head evaluation, intraocular pressure (applanation). According to the findings, following population based strategies are adopted:

   Group A patients Normal. Criteria of normalcy in defined geographic areas are: (1) normal cornea and ocular media as determined by slit lamp, (2) normal pupillomotor function without any afferent pupillary defect, (3) normal ocular motility, (4) minimum corrected visual acquity 6/18 OU, (5) refractive error of 5.75 or less and

Table 6.3: Screening schedule of patients

GroupA		Group B		Group C	
Screening standard		Screening precision		Screening glaucoma	
positive	negative	positive	negative	positive	negative
1. Central 30^{o} threshold 2. Supra-threshold blind-spot protocol 3. Serial supra-threshold field and custom programme 4. If needed, 30^{o} circle threshold sensitivity.	1. Field may be repeated after two months	1. Same as in group A; only screening glaucoma and suprathreshold peripheral strategy may be needed.	1. Central threshold 2. Repeat field after two months.	1. Same as group B, followed by B a. Isopter protocol b. Suprathreshold macular 8 degree programme, to assess post-operative visual prognosis, if the patient needs drainage procedures.	1. Same as group

2.00 Dcyl or less, (6) symmetrical IOP of less than 20 Torr in BE, with a difference between eyes of less than 3 Torr, as measured by Goldmann applanation tonometry, (7) Morphologically normal optic nerve with symmetrical C:D ratio less than 0.5, (8) normal visual fields by confrontation, (9) no concurrent systemic disease, (10) negative family history for glaucoma.

Group B patients: Where 3 of the above criteria are abnormal, but pupil function intact, IOP more than 20 Torr, difference between eyes more than 3, but less than 5 Torr, and no gross morphological aberration of optic nerve.

Group C patients: Where more than 6 of the above criteria are abnormal. IOP greater than 21 torr, difference between eyes more than 6 Torr; cupping more than 0.5; pale neuroretinal rim, positive family history.

B. Table 6.3.

C. Most important protocol is central 30^{o} threshold value estimation where the quantification of retinal sensitivity at 76 predetermined test locations with 6^{o} resolution for effective grid spacing, are determined (30-1, 30-2 in Humphrey, GI 61 in Octopus, screening glaucoma in Kowa). Here also peripheral strategic Armaly-Drance spots are coupled with to pick up any 'nasal step' defect. Peripheral 30-60^{o} protocols are not important clinically. In case of possible error with trial frame rim artifacts resulting in high false-positive results, central 24-1 and 24-2 programmes; and in patients of advanced field loss, central 10^{o} field are necessary. Octopus has the advantage of its "phase" programme. In phase I, MD and LV are calculated, in phase II, re-thresholding and SF, CLV are calculated in response to high value of MD and IV in phase I. Phase III implies "nasal step" screening, if values of MD and LV are normal in phase I.

D. In Kowa, special vertical meridian screening helps to rule out any retinal desensitivity of neurologic origin. Had it been present, usually referred to as "hemianopsic offset", due to abnormal cliff in retinal sensitivity, indicative of a "pathway" lesion. Also to remember in

this context that in late stage of glaucoma, vertical step of Lynn may be present.

E. Isopter protocol available with/without threshold programming. Very important in pre-advanced and advanced Glaucoma cases — where both diagnostic and prognostic information can be sorted by observing 'softening', 'scattering', 'notching', 'eating' of isopters.

CRITERIA USED FOR INTERPRETATION OF CENTRAL VISUAL FIELDS (CVF) WITHOUT ISOPTER PATTERN (Figs 6.42 A to K) (Table 6.4)

CRITERIA USED FOR INTERPRETATION OF PERIPHERAL VISUAL FIELDS

Interpretations	*Criteria*
A. Normal field	A. None of the following defects
B. Questionable defect	B. Questionable defect
a. Nasal hemianopsic offset	a. 10^{o} or more offset, nasal to vertical meridian
b. Peripheral constriction, other than nasal quadrant	b. 'A' isopter inside 50 temporally, 40 inferiorly, 30 superiorly; 'B' isopter inside 40 temporal, 30 inferior, 30 superiorly.
C. Glaucomatous Defect	C. Glaucomatous Defect
a. Nasal step	a. 10^{o} or more offset, above or below horizontal nasal mid-line
b. Nasal peripheral constriction	b. 'A' inside 30, 'B' inside 30
c. Temporal sector defect	c. 20^{o} or more defect towards blind-spot in temporal quadrant
d. Temporal hemianopsic offset	d. 10^{o} or more offset temporal to vertical meridian

D. *Follow-up of patients:* In subsequent visits, to detect any progression of field loss, change of slope, increase in defect depth, or variation of isopter pattern and contour; the patients are subjected to (a) Supra-threshold diagnostic or quadrant protocol, (b) Repeat isopter-threshold programme, (c) Linear custom 10,20, 30 degrees supra-threshold analysis.

Table 6.4: Interpretation criteria of CVF

Interpretations	*Criteria*
A. Normal visual field	A. None of the following defects
B. Questionable defects	B. Questionable defects
a. Paracentral depression	a. 2-5 non-contiguous defects in Bjerrum's
b. Enlarged blind-spot	b. 2-5 non contiguous defects adjacent to blind spot, but not all in Bjerrums area
c. Peripheral depression	c. Greater than or equal to 3 contiguous defects, peripheral to Bjerrum's area
d. Central depression	d. Defects central to Bjerrum's area
e. diffuse depression	e. Defects of same magnitude throughout the field.
C. Glaucomatous defect	C. Glaucomatous defect
a. Paracentral scotoma	a. 2-5 contiguous defects in Bjerrum's area
b. Seidel's scotoma	b. 2-5 contiguous defects, adjacent to blind-spot in Bjerrum's area
c. Arcuate scotoma	c. Greater than or equal to 6 contiguous defects in Bjerrum's area (single/double)
d. Nasal step	Greater than or equal to 2 defects above or below horizontal mid-line in nasal periphery.

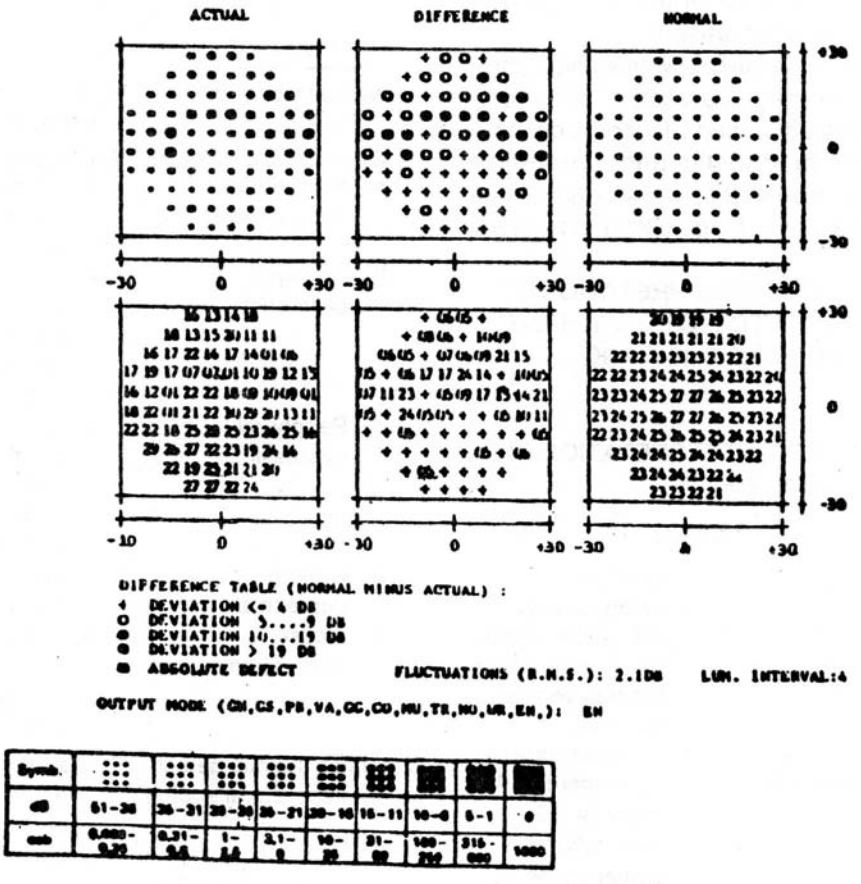


Fig. 6.42A

E. Analysis of data and estimation of probability value. The Octopus delta and trend protocols compare several visual fields from the same patient. The global GI programme attempts to separate different variables.

FACTORS AFFECTING VISUAL FIELD TEST RESULTS

A. Physiological Factors

Visual acuity Minimum requirement 6/18 of Snellen's acuity chart to avoid false desensitive zones in retinal neuro-sensory element.

Age related changes Obvious decline in mean sensitivity as well as volume and surface area of the visual field is seen, due to age-related progressive qualitative and quantitative loss of neuroretinal, and possibly higher structures. There appears to be a larger decline in sensitivity; the further, and the superior, the point is from fixation. This is corroborated as a function of eccentricity and differential ganglion cell decay. The eccentricity and increased variability of the visual field with high RMS fluctuation (2.5 dB) often misinterprets an isolated depression as a true pathologic defect. Thus, for prospective study to evaluate patients with known or suspected ocular abnormalities on basis of statistical methods, unbiased, age-matched adjustment of 0.1 dB/year is incorporated in automated perimeter (Figs. 6.43 and 6.44).

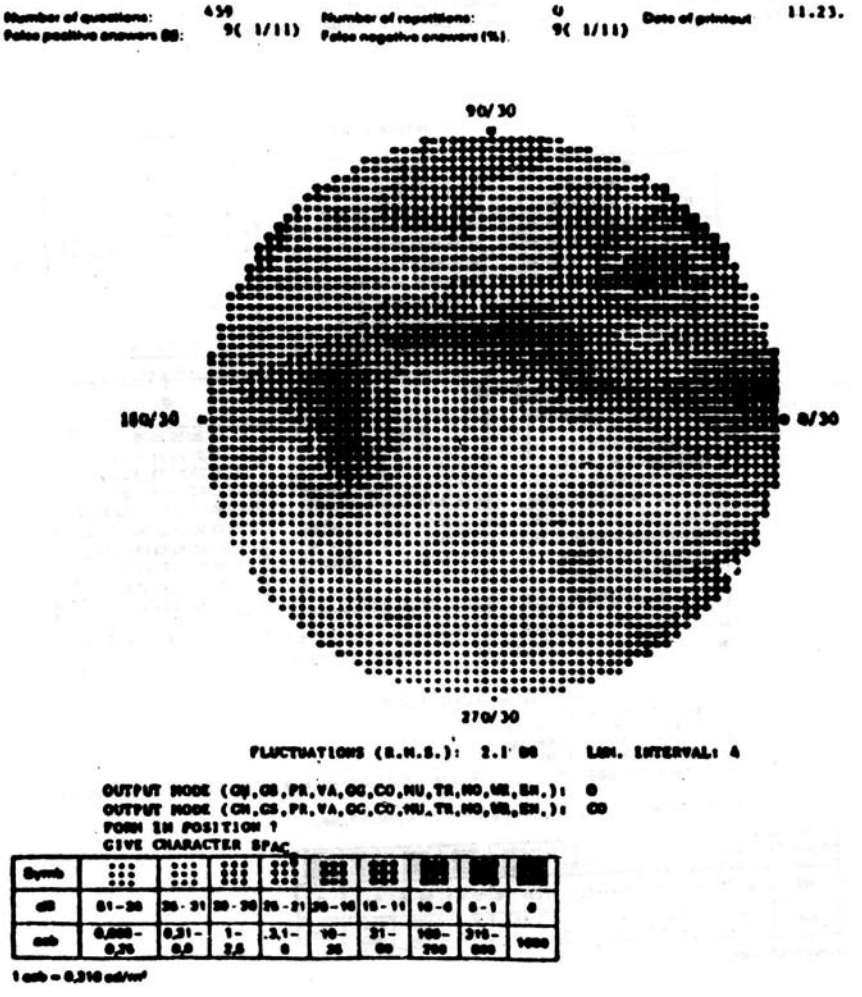


Fig. 6.42B

Refractive errors Hyperopia, presbyopia, myopia more than 3D, etc. may influence perimetric testing of central 30° field. For each dioptre D of increase in refractive power, there is a reduction of 26.5 dB in summated retinal sensitivity; corresponding to a 1.26 dB average decrease at each point in central 6 degrees of visual field. The average slope of the regression of retinal sensitivity on distance from fixation is -0.337 dB. The slope does not appear to depend on refractive error within the central 6 degrees of visual field. Since these refractive errors can resemble generalised depression of the paracentral region of the visual field, which may be the earliest damage in some patients with glaucoma, it is important to use appropriate and accurate refractive correction during visual field examination with automated perimetry.

Pupil size Pupil diameter less than 3 mm is known to exhibit peripheral depression, and 'notching' of central isopter; and may exaggerate previous visual field defects.

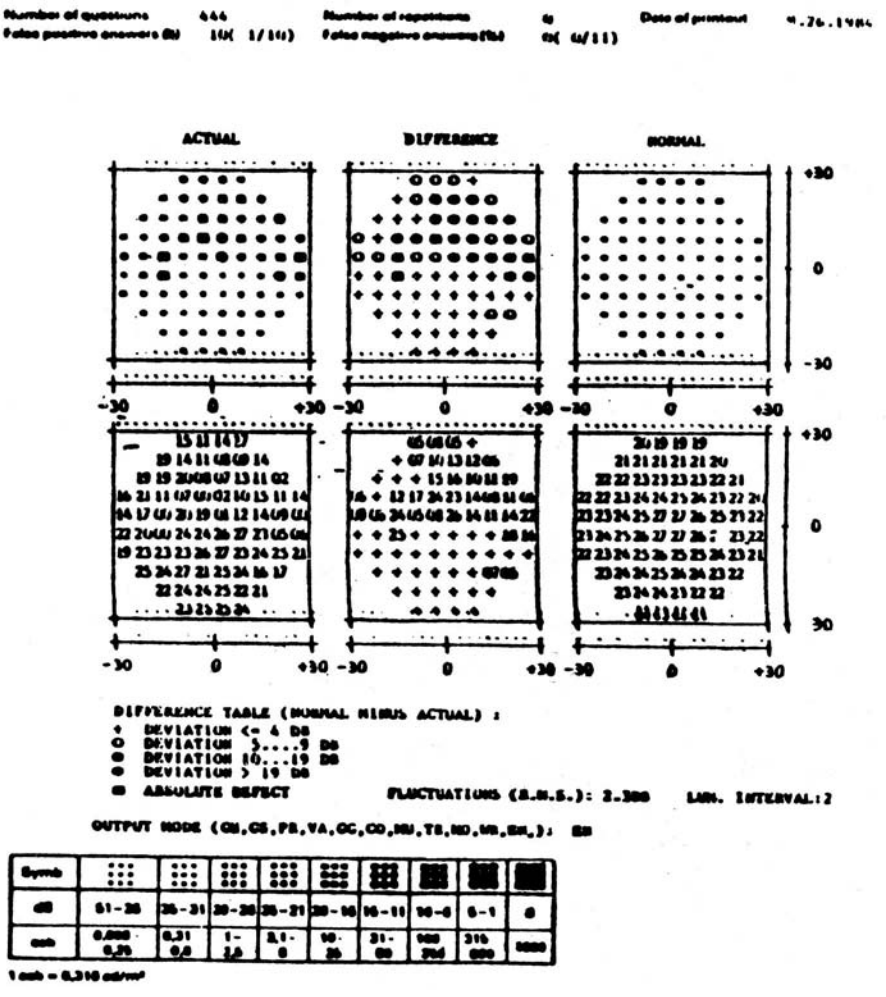


Fig. 6.42C

Clarity of media Any central visual axis blockage due to cornea, lens or vitreous factor produce exaggeration of both central and peripheral defects by their optical function, known as "modulation transformation system".

Psychological Factors

1. Experience of previous perimetric exercise.
2. Patient's understanding of the test protocol.
3. Patient's consciousness, alertness, attentiveness, and co-operation during the test.
4. Good fixation ability, without eccentric decompensation.

Newer readily available APs like Octopus, Kowa, Humphrey, especially when used with the statistical analysis package, resolve problems of data interpretation, as the computer software analyses the raw data and puts it in a readily understandable form. A gray scale shows a map of the 'hill of vision', with darkness proportionate to loss of sensitivity. The mean difference from the expected result is displayed numerically, as is the difference from the normal age-matched population. Finally a probability map exhibits the likelihood of a defect, being a variation of the normal.

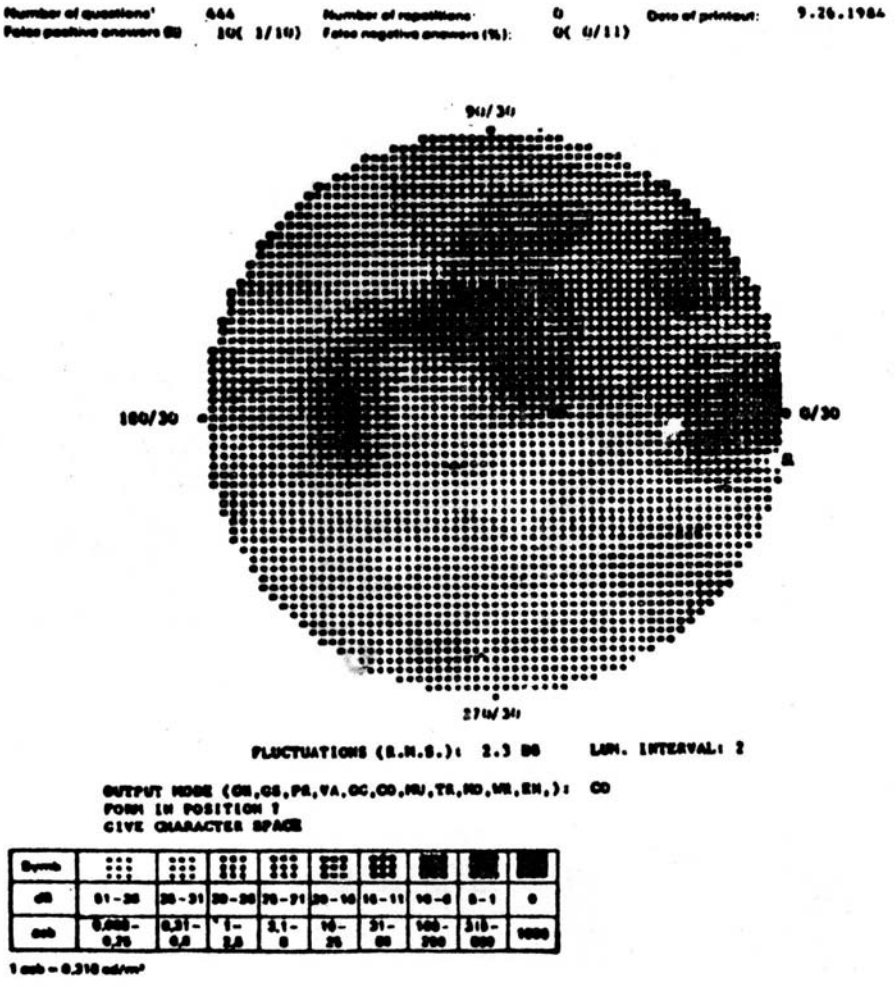


Fig. 6.42D

Visual Field Indices

Collection, interpretation, and comparison of serial visual fields with APs are facilitated by measurements, called visual field indices, or global indices. These are as follows:

Differential light threshold It refers to the ability of the visual system to detect a difference in contrast between two light source of different luminance, i.e. the test target and the background illuminance.

Mean sensitivity Average threshold value of all the test locations in a single visual field, useful in detecting diffuse changes.

Average sensitivity It refers to comparative analysis of measured mean retinal sensitivity of a test point and that of age-corrected normal threshold value of the same point.

Pointwise threshold values Pointwise difference between the measured threshold of the first test, and successive tests obtained by customised single quadrant protocol. The group average of these differences is calculated, and computed onto a probability map.

Mean deviation Deficit in decibels from a normal age-matched population is presented showing overall differences in sensitivity from normal. A

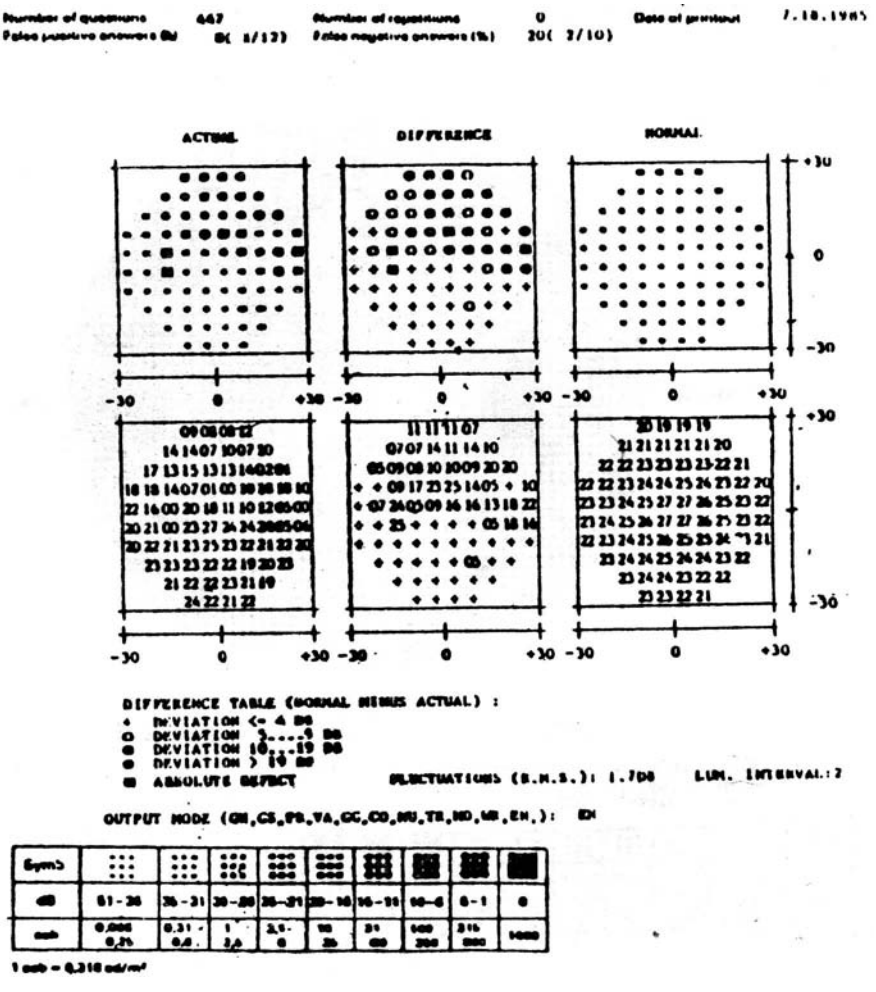


Fig. 6.42E

depression of this value in the absence of other pathology is indicative of glaucoma.

Total loss It is the sum of the differences between the age—corrected normal value for each test location, and the measured threshold for each test location. In calculating total loss, test locations with differences of less than 4 dB are ignored as are test locations where, the threshold measurement is greater than the expected age-corrected normal. Total loss reflects both local and diffuse loss of sensitivity, but does not distinguish between them.

Variation in threshold Short- and long-term fluctuation: Short-term, during a single visual field examination, being on the order of 0.18 log units. Many perimeters provide an estimate of SF as the root mean square (RMS) value. It is determined by performing double threshold determinations at a strategic number of test points. Thus it is an estimation by which the threshold fluctuates between the 'seeing' and 'non-seeing' during the course of the test. A high SF appearing on a field with good reliability markers may be one of the earliest evidence of glaucomatous damage. Long-term fluctuation refers to apparent change in

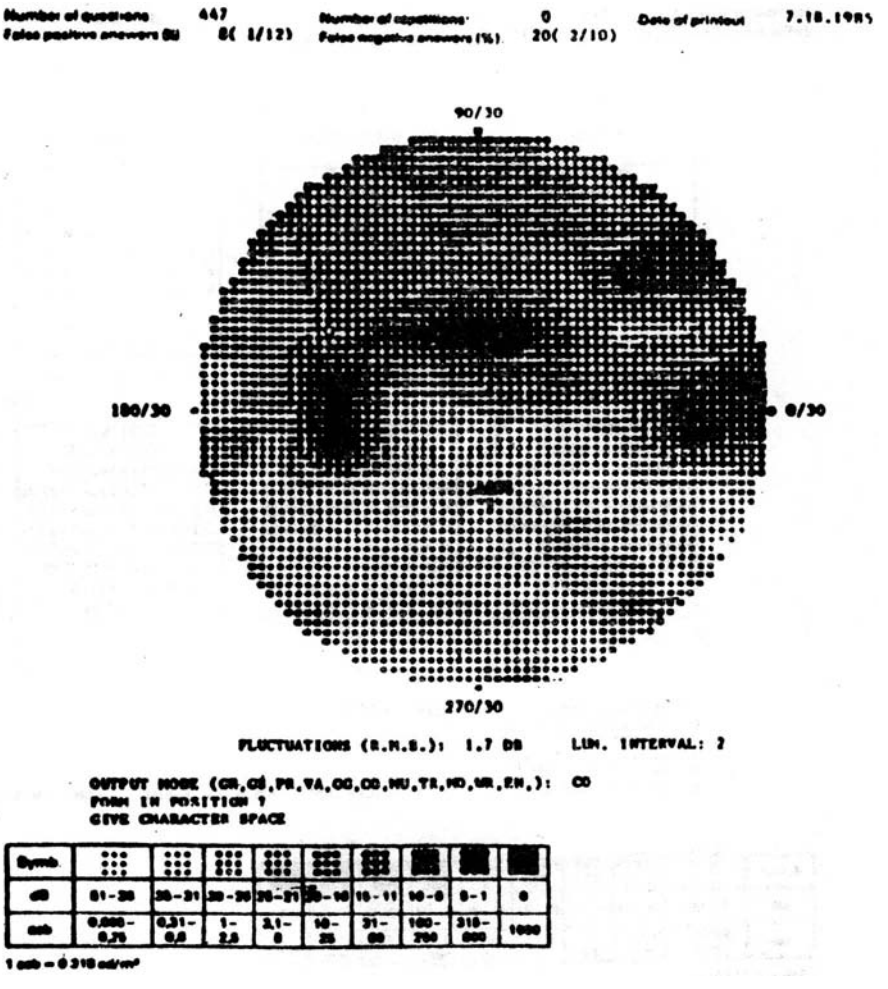


Fig. 6.42F

sensitivity between two successive fields, without worsening of pathology. LTF is on the order of 0.07 log units of luminance.

Corrected loss variance (CLV) It projects an idea about the local non-uniformity of the visual field, corrected for SF. It is calculated from the difference between the test results and the expected results from an age-corrected normal database, with SF taken into account. Thus, a localised scotoma may cause little depression of MD, but will give rise to an abnormal CLV as this measurement corrects for intratest variability.

Skewness (Q) It measures the distribution of the deviations of the measured from the expected values.

Spatial correction (SC) Similar to CLV, but considers the location of defects, being sensitive to defects, clustered in one area of the visual field.

Pattern standard deviation (PSD) It is a measurement of uniformity of visual field and is determined by comparing the shape of the patient's measured field to an age-corrected, reference field. Low

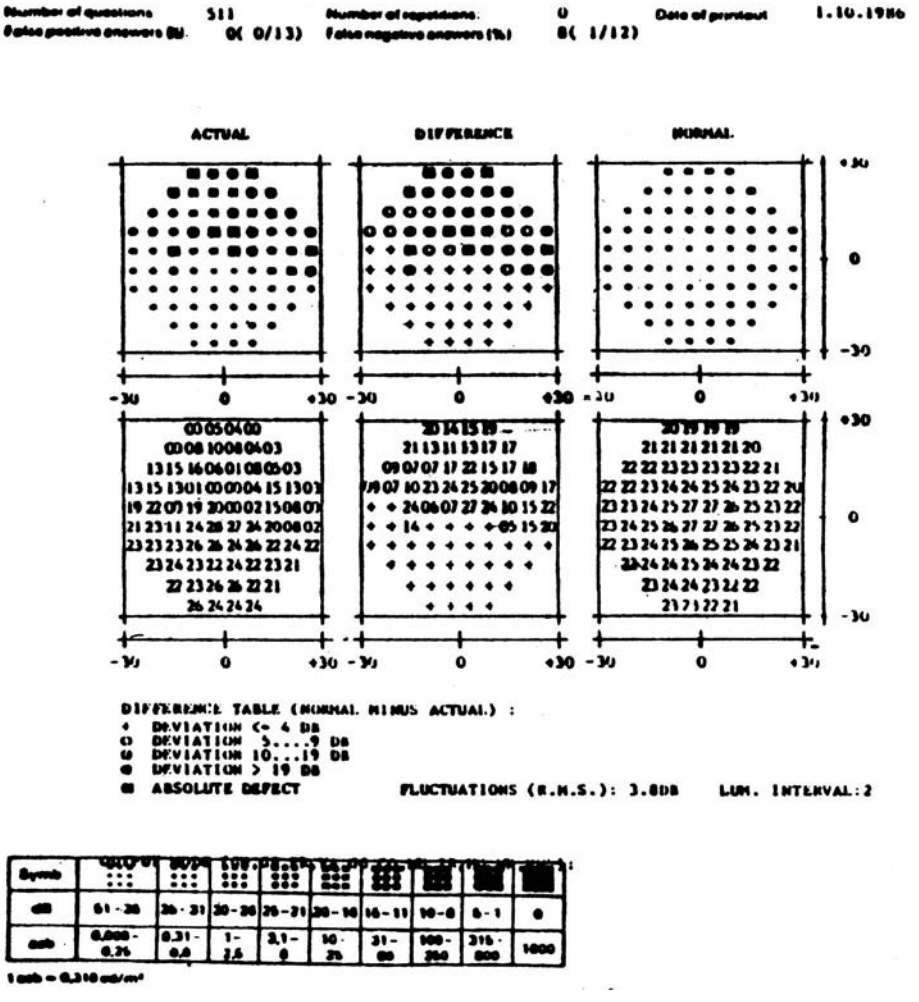


Fig. 6.42G

PSD indicates smooth 'hill of vision'. High PSD indicates an irregular 'hill', which may be due to variability in patient's responses or to actual localised field defects. A general change of sensitivity will not influence PSD.

Corrected pattern standard deviation (CPSD) Measurement of the uniformity of the shape of the 'hill of vision' after the effect of SF has been removed. It is similar to CLV. A high CPSD usually indicates the presence of true localised field defects even in the presence of a high SF or generalised loss of sensitivity.

The PAD and CPSD are related by $CPSD^2 = PSD^2 - SF^2$

Learning factor It refers to the improvement in the Mean Threshold between the first test and test results obtained from successive sessions by less than 3 decibles. This is correlated with age by Spearman's rank coefficient.

Isopter The limit between the peripheral area where seeing ceases and the inside area where seeing occurs is called an isopter. In the mathematical sense, an isopter is the locus of similar

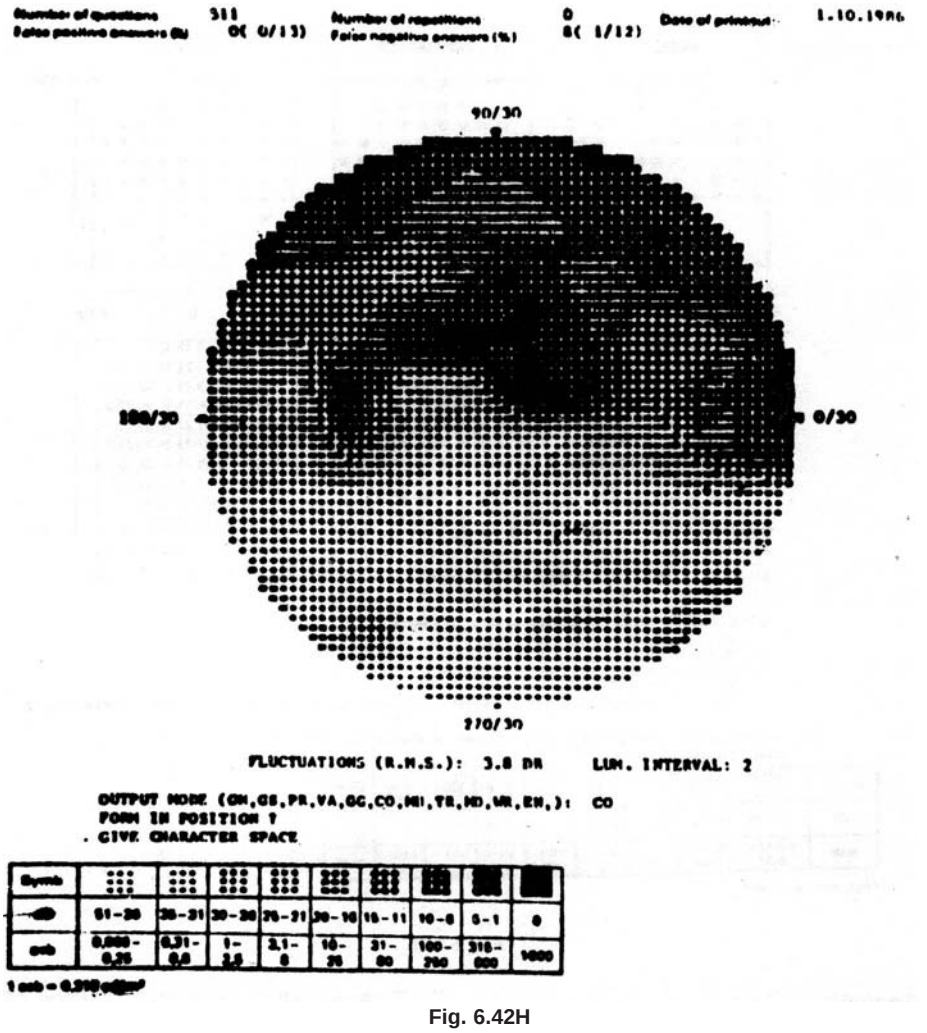


Fig. 6.42H

visual threshold determination, or in the ophthalmological sense, a line joining points of equal retinal sensitivity. Isopters are thus recognised as a family of curves, normally ovoid, which describe the variable sensitivity of the eye. The zones of increasing visual sensitivity resemble a family of conoids with their apexes at the pupil and their progressively small bases, oriented around the optical axis of the eye.

Indices of Patient Reliability

False-positive responses These occur, when the patient responds to a target, that is not there. To detect this 'Trigger-Happy' patient, the machine occasionally makes the noise associated with stimulus presentation at a time, when no stimulus is presented.

False-negative responses The inattentive patient is recognised, when a stimulus in an area of the visual field he or she has responded previously, is not reciprocated on repeat presentation usually with a supra-threshold luminance.

High false-positive and false-negative results refer to fixation loss. If this value is more than 20 per cent the reliabilities of datas are nullified.

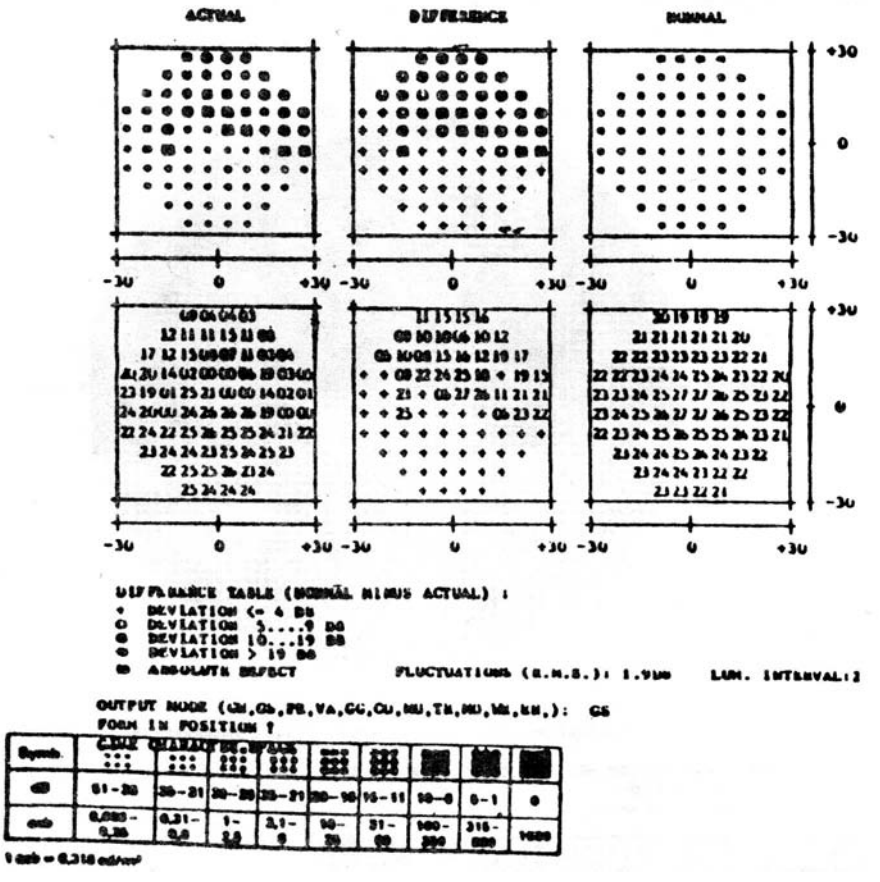


Fig. 6.42I

Statistical Analysis of Data

Statistical analysis of visual field data applies a statistical test, and looks for its statistical significance.

A. The delta programme in Octopus is a paired test, that compares the mean sensitivities of two fields or two groups (Fig. 6.45).
B. Anaylsis of variance is a technique, that compares the mean sensitivities of multiple fields, and can detect significant changes over time.
C. Regression analysis and correlation coefficient on various visual field indices can be performed to see, if there is significant correlation of a change with time. The Statpac programme, available with the Humphrey utilises regression analysis (Figs 6.46 to 6.48).
D. These statistical tests are heavily dependent on sample size and distribution. The number of test locations, and the number of examinations have good impact on the outcome of the test.
E. Patients with large amounts of fluctuation can appear to be progressing, even if, in fact they are not. Tests of statistical significance can be skewed by large amounts of LTF.

Population-based Perimetric Probability Map

Automated visual field charts may be difficult to interpret, partly because of the magnitude and complex nature of normal threshold variability. Simple rules of thumb cannot adequately describe it; and it is impossible to memorise all

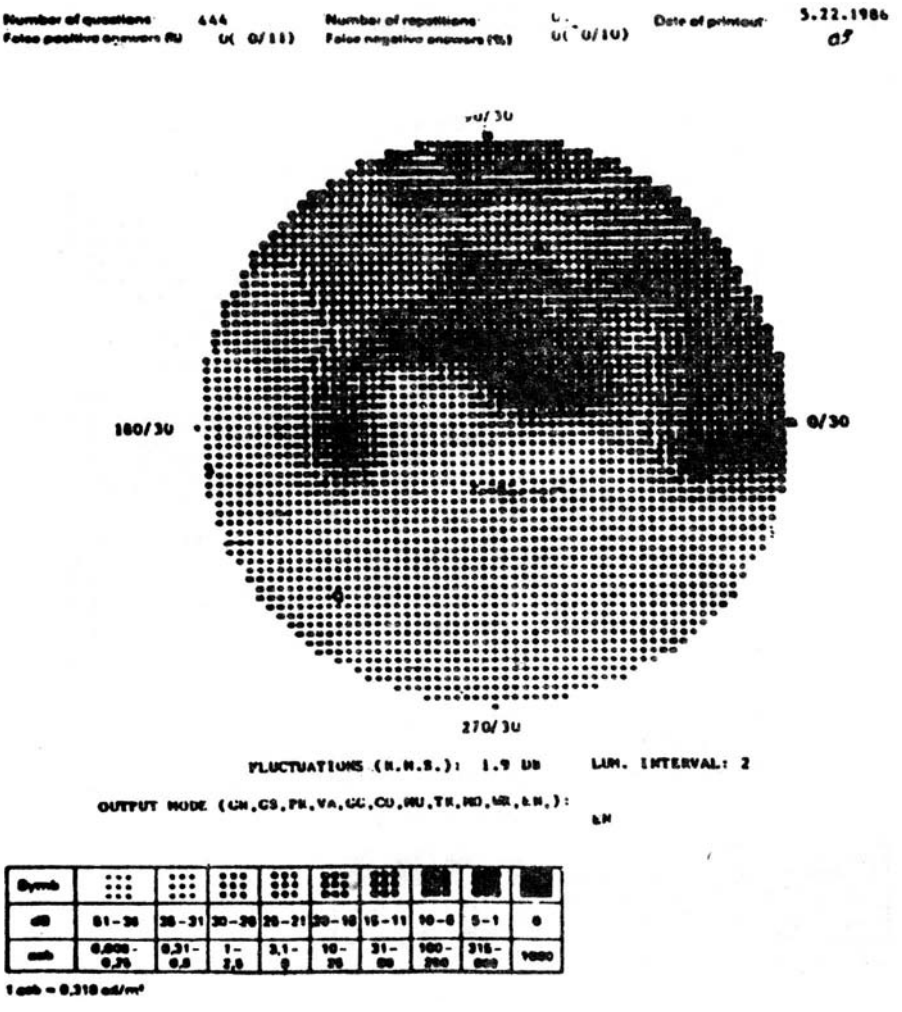


Fig. 6.42J

the various limits required to reach any statistical significance across the visual field. The computer of the perimeter, however, can easily calculate and display graphically those probabilities, on the basis of the distribution in a large pool of normal data. Thus a perimetric probability map depicts the possible frequency, in which the measured findings are deviated from an age-matched population, in a defined geographic area. In probability map, the much in vogue, emperically determined, non-gaussian model uses threshold distributions on test point locations — the significance thus calculated is plotted in two dimentional gray scaled probability maps, yielding relative operative characteristic (ROC) curve, where sensitivity and specificity are strongly coupled. Designing of this map requires previous perimetric experience of the patient, and certain minimum reliability criteria; less than 20 per cent fixation loss, 33 per cent false-positive and 33 per cent false-negative answers. In cases with obviously normal or

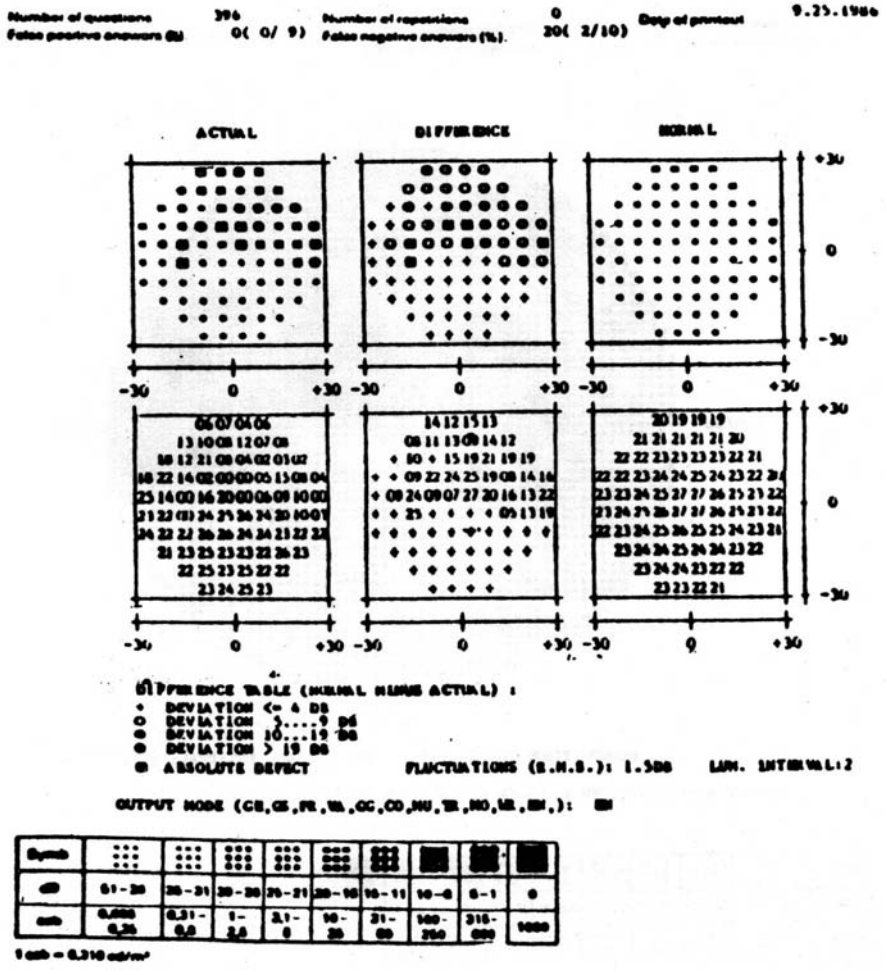


Fig. 6.42K

Figs 6.42 A to K: Visual fields obtained on a patient over a period of nearly 3 years show progressive plan comatous loss in the left eye. The superior arcuate scotoma has become denser and larger over time. The dates of the examinations were (A,B) 11/23/83, (C,D) 9/26/84, (E,F) 7/18/85, (G,M) 1/10/86, (I,J) 5/22/86 (Figure continues)

clearly abnormal test results, empirical probability maps do not add much, but only confirm the findings of the conventional printouts. But these are of immense help between the clear and abnormal zones in the gray scale. They are highly sensitive to nonobvious but significant paracentral field loss, and at the same time deemphasises false-positive patterns commonly found more peripherally; thus disregards drooping of lids, trial lens artifacts, modulation transformation function of refractive errors and immature lens changes. They also frequently show field defects, before these are obvious in conventional threshold printouts. In addition, they differentiate between generalised loss of sensitivity and localised field defects. For the interpretation of single field chart, it therefore makes more sense to rely on empiric probability map; where the spatial relations of disturbed points are clear than on visual field indices, described earlier (Fig. 6.49 A to D).

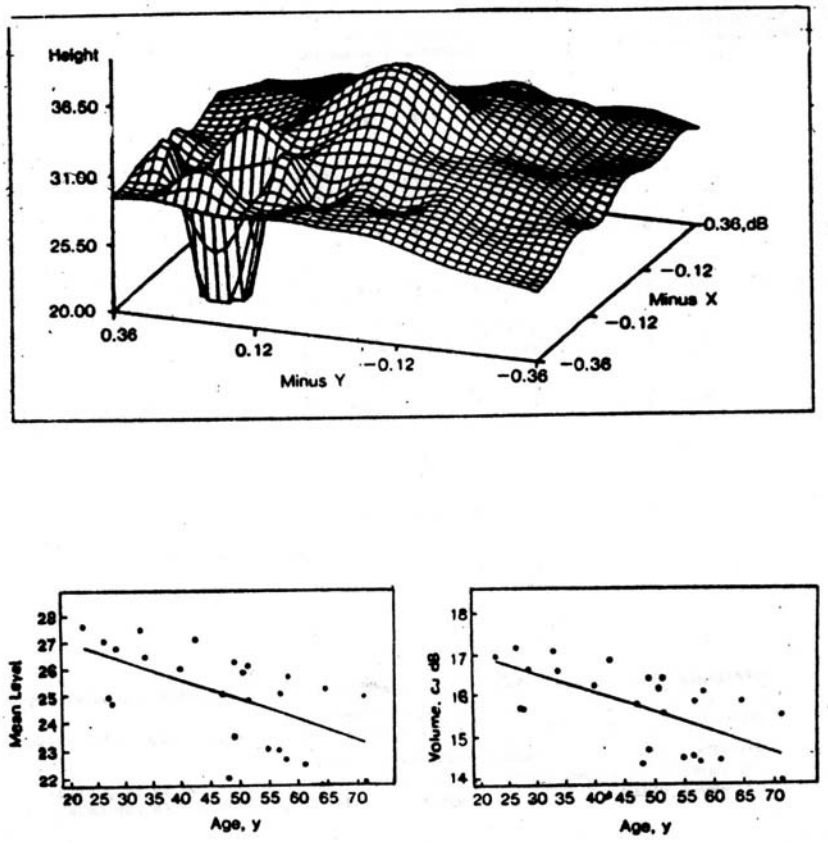


Fig. 6.43: Computer-generated three-dimensional graphic representation of normal visual field. Age-related decline in mean threshold sensitivity for first eye tested. Estimated regression: sensitivity (decibel) = 28.8 - 0.074 x age (years). Rate of decline in volume of visual field as function of age, for eye tested first. Estimated regression: volume (cubic decibel) = 18.0 - 0.048 x age (years)

NEWER APPLICATIONS OF AUTOMATED PERIMETORY

Change Analysis

This display will have graphical change analysis summary of all the global indices, though only the progressive behaviour of the mean deviation (MD) and corrected pattern standard deviation (CPSD) are useful. Five tests are needed for analysis, but the statpac will automatically discard the first test if its results are inconsistent with subsequent examinations because of the learning curve.

1. If general deterioration or improvement of the mean deviation has occurred its slope will be as with or outside normal limits. (a) Positive mean deviation changes often reflect increased clarity or improvement due to a learning curve. (b) Negative changes frequently mean decreased sensitivity from impaired ocular media or progressive disease.
2. Focally increasing scotoma will manifest as progressive falling off the CPSD values (in dB) over time.

Box-plot

This histogram summarises the threshold profile of all the points from each field and plots these boxes over time with a dB scale to indicate their deviations from age matched normal. On left side

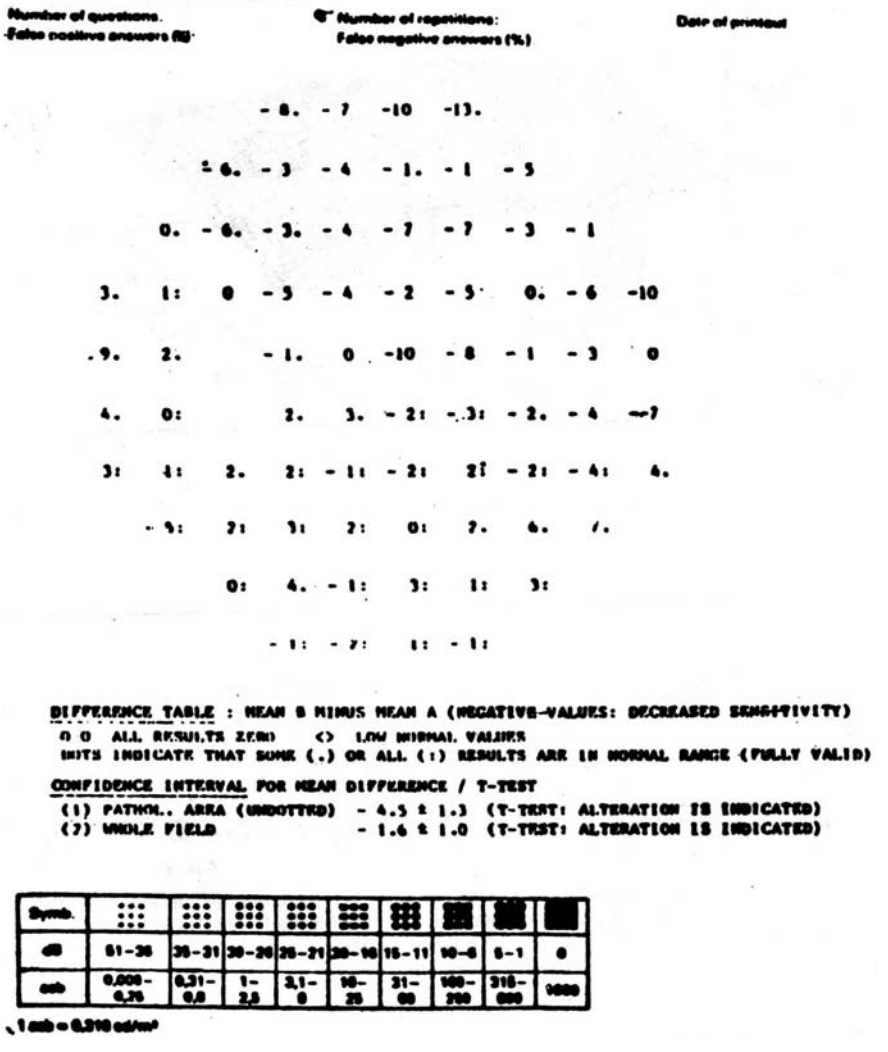


Fig. 6.44: A paired test comparing the sensitivities of the first two fields with last two fields shows a statistically significant change in the visual field over time

there is a labelled box which represents the values of the normal field. Field's 15 per cent test threshold points appear as the upper tail on the top of the box, field's 15 per cent worst points are represented by the bottom tail. Remaining of 70 per cent of the field vales are represented by the box (Fig. 6.50).

Three features that helps in interpretation are the following:

a. length of the tails,
b. length of the boxes, and
c. relative positions of the boxes compared to normal and to one another.

An improvement in threshold testing such as from learning curve or after cataract removal could manifest as contraction of the box length and its line up to odB line. When cataract causes generalised depressed sensitivity the box will be like a normal one but the entire box and it median value would sink. When focal scotoma occurs

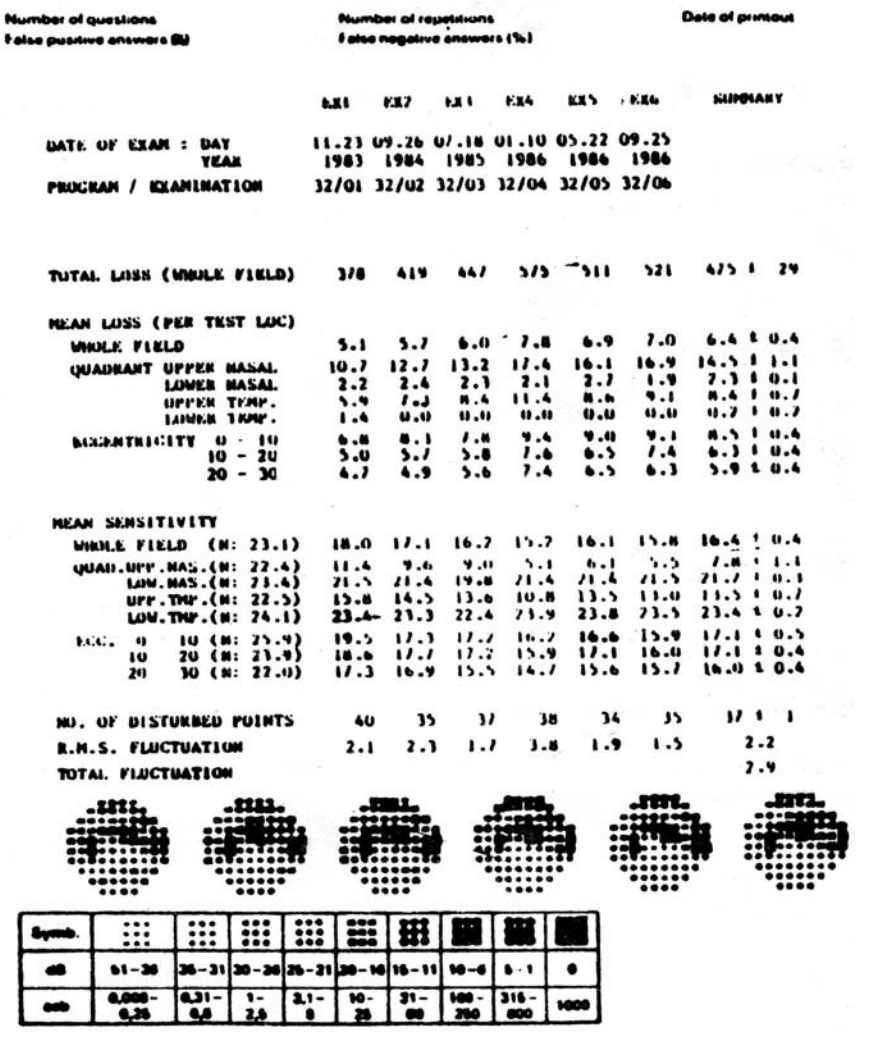


Fig. 6.45: Delta programme printout of the patient. (A) The series printout summarises each visual field in chronologic order. One can see a gradual increase in total loss over time, indicating progressive loss. Reviewing the mean sensitivity has been in the upper nasal quadrant

without generalised field change the lower tail of the curve would be relatively extended reflecting the deeping of the localised scotoma manifesting among the worst 15 per cent of points. Combinations of large scotoma and diffuse damage often involve nearly all the test points, so the boxes elongate downwards.

Overview Format

16 tests can be printed as a single sheet with four basic displays, the gray scale, raw numeric data, probability maps of total deviation and pattern standard deviation.

Ancillary information runs along the margins, along the upper border runs the data of the test,

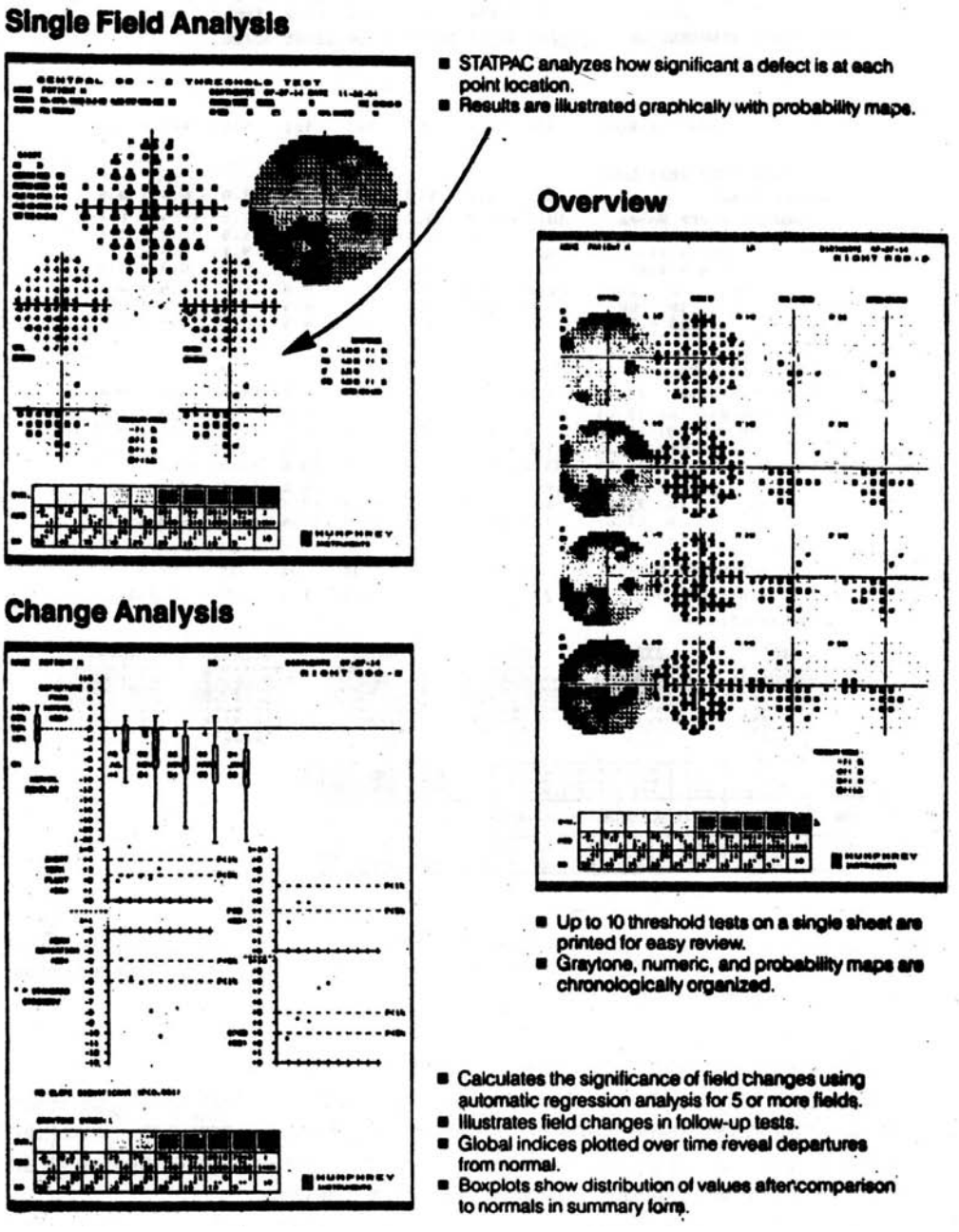


Fig. 6.46: Humhrey field anaylser statistical software

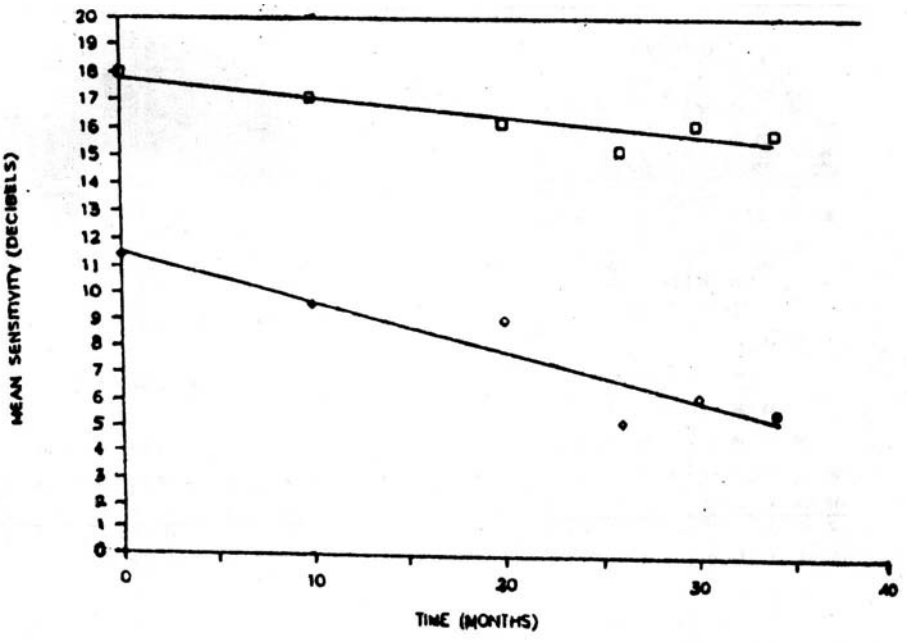


Fig. 6.47: Regression analysis performed on the visual fields of the patient. There has been a significant deterioration of the overall mean sensitivity of the whole visual field (open squares), while the deterioration of the upper nasal area (diamonds) has been even more pronounced

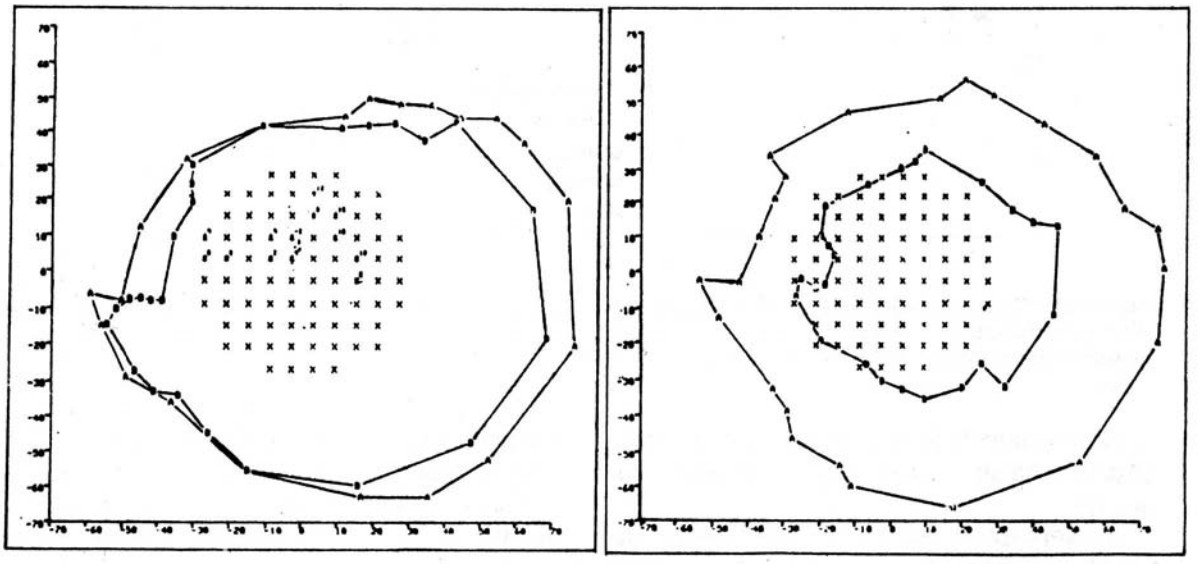


Fig. 6.48

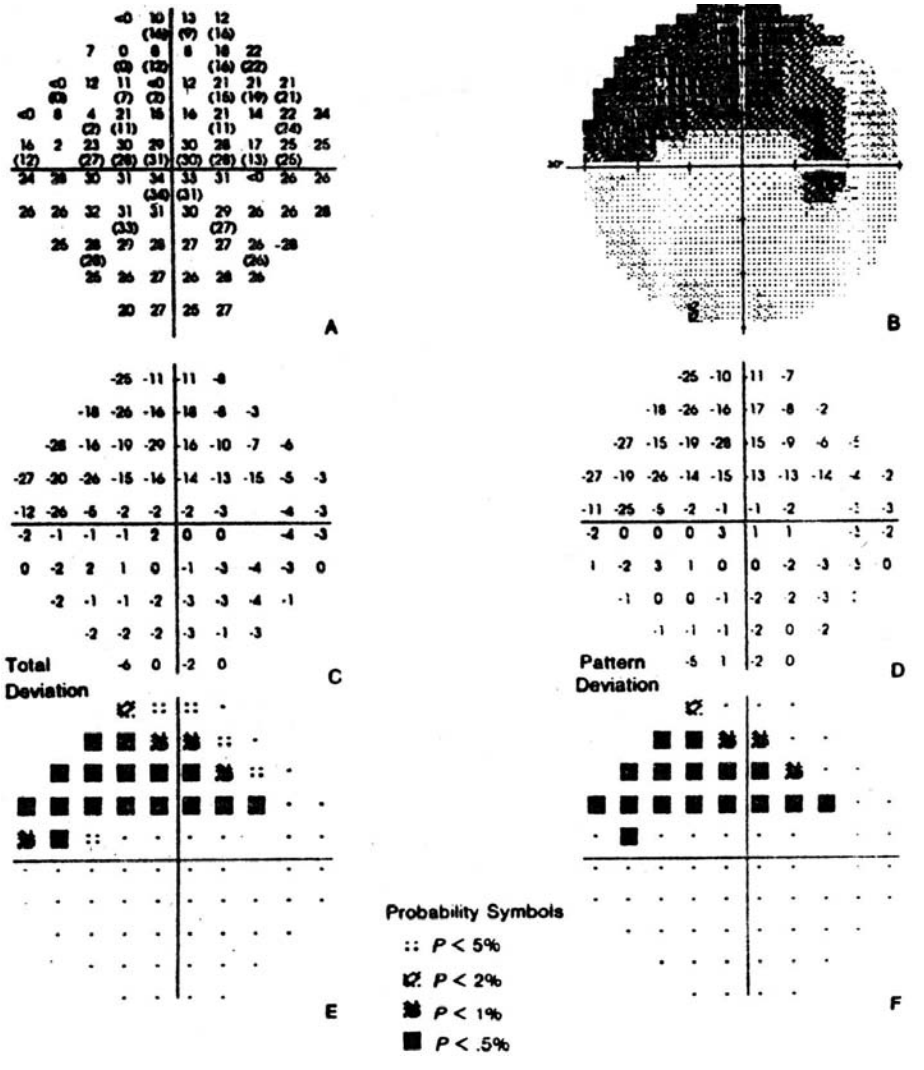


Fig. 6.49A: Glaucomatous field with classic arcuate defect. Defect is obvious in traditional numerical (A) and gray-scaled (B) threshold charts as well as in numerical total deviation (C) and pattern deviation (D) maps. Total deviation (E) and pattern deviation (F) probability maps only confirm defect

glaucoma hemifield test, fixation losses, false-negative, false-positive, pupil size and visual acuity.

Lower caption includes foveal threshold value (FOV), mean deviation, pattern standard deviation, short-term fluctuation and corrected pattern standard deviation.

Glaucoma Change Probability Analysis

It has access to an empiric database derived from clinically stable glaucoma patients to assess whether suspects or glaucoma patients have progressive field defects.

The first step is establishment of a baseline which is composited from two selected tests.

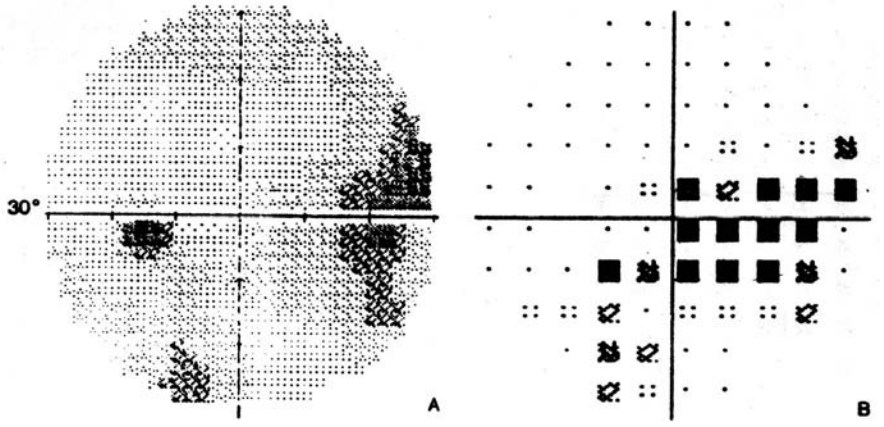


Fig. 6.49B: Extent of field defects may often be more obvious in probability maps than in traditional gray-scaled threshold representation (A). In this glaucomatous field, total deviation probability map (B) clearly shows that inferior defect extends from blind spot nasal periphery

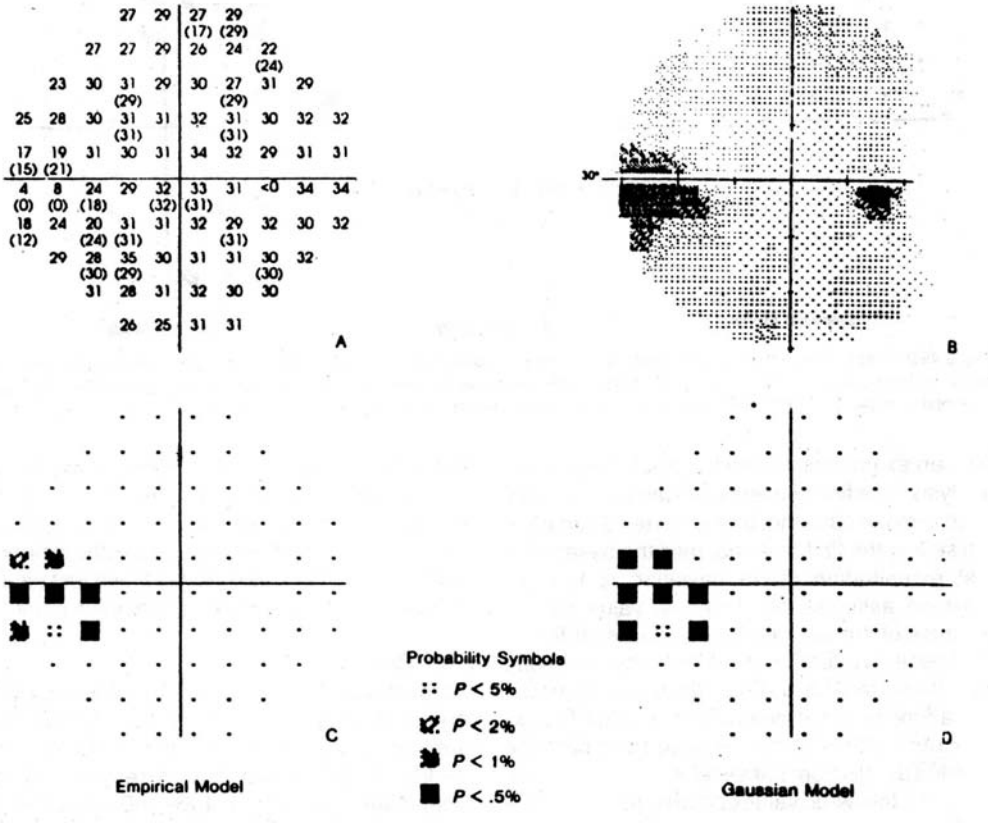


Fig. 6.49C: Four representations of glaucomatous visual field. Standard threshold (A) and gray-scale (B) printout. Probability map of deviations from age-normal values, based on empiric model (C) gaussian model (D)

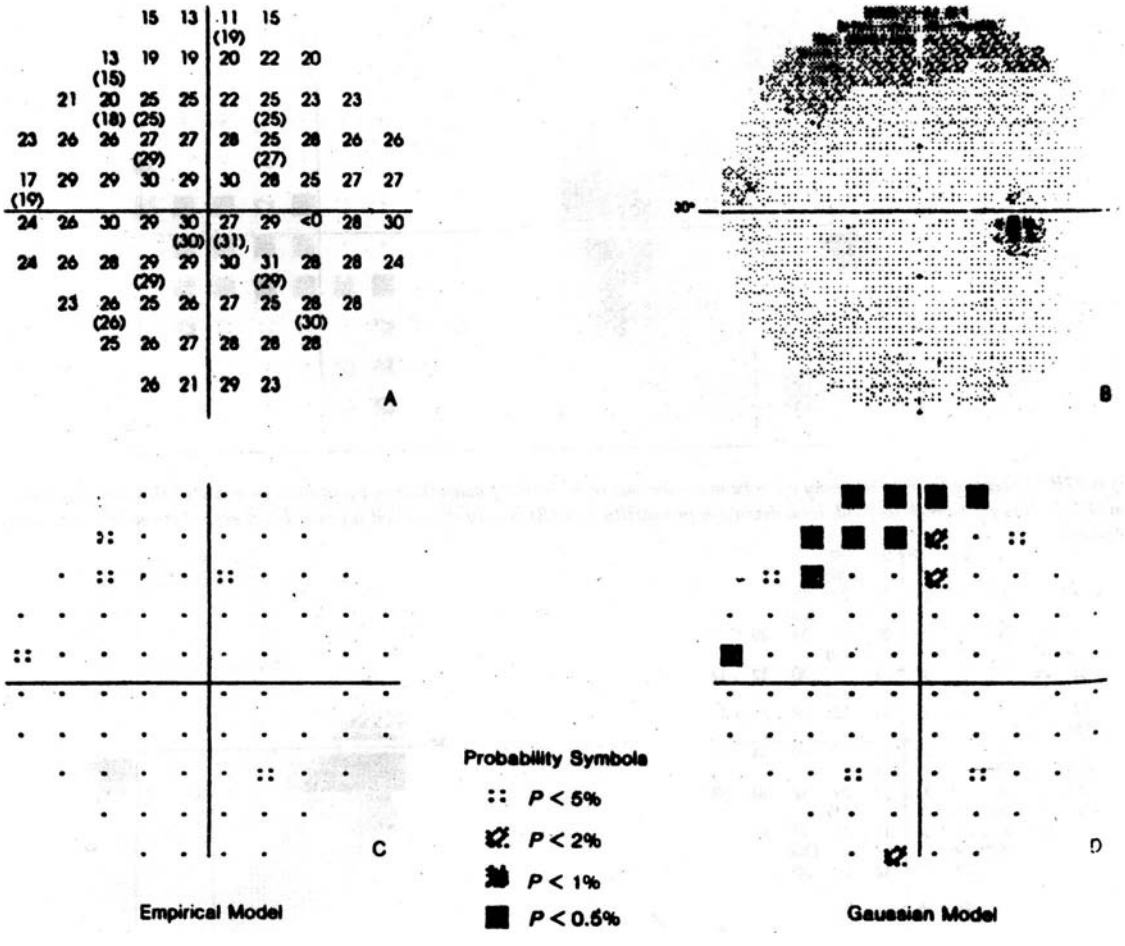


Fig. 6.49D: Field from normal subject. Shallow depression is seen in upper midperiphery in standard threshold (A) and gray-scale (B) printouts. Such depressions occur frequently in normal subjects and are deemphasised by probability map based on empiric model (C). Probability map based on gaussian model (D), however, falsely indicates that the finding is rare

Sixteen examinations can be processed by this analysis. The first two tests available are usually used to make baseline. If only two tests comprise the series, the first one becomes the baseline. If first examination mean deviation is too low machine assumes the first test value as low because of the learning curve and discards it.

These two tests are printed together along with their identifying data, glaucoma hemitest, foveal threshold and mean deviation value. Follow-up examinations shows change from baseline labelled as “dB from baseline” which simply subtracts the follow-up values point by point from the baseline and expresses the difference as positive or negative numbers in dB. Next to this is the change probability map labelled on the page as glaucoma probability which indicates the statistical significance of the dB changes when test data is compared to the baseline data at each point.

Fast Pac

It includes ability to run screening tests based on age~reference levels for the threshold-related strategy. It reduces the test time by 40 per cent. In full threshold strategy, threshold will be

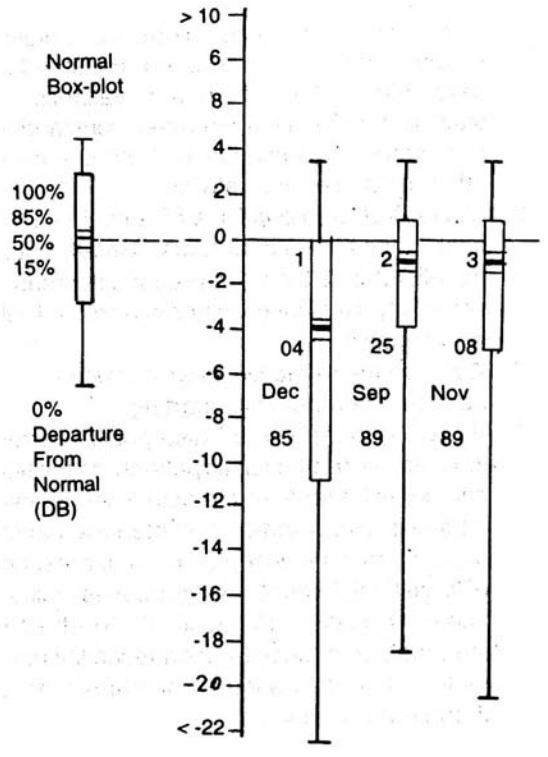


Fig. 6.50: "Box-plot" display from the Humphrey field analyser. The symbols allow ready comparison of statistically reduced data from a series of field examinations

determined by using a 4dB~2dB staircase. In fast-pac threshold points are tested only once using increments of 3dB. When the value is lower than expected the point will be checked second time in steps of 3dB. Programmes such as overview and change analysis are available. Whenever it is used, "fast pac" is indicated in each of the printouts. As this strategy is not performed with glaucoma population, glaucoma change probability analysis can't be evaluated.

Oculokinetic Perimetry (OKP)

Here the test stimulus remains stationary and the patient is asked to move the eye to various locations. When oculokinetic perimetry was calibrated to automated perimetric threshold value, 50 per cent frequency of the observed oculokinetic perimetry stimulus was roughly equivalent to a 15 dB stimulus on Humphrey field analyser.

High-Pass Resolution Perimetry (HRP)

It consists of a series of "ring" targets of varying size. These targets are generated on a video monitor which will have light circular centre and a dark annular surround. Main advantages of this method are relatively quick examination time, and high degree of patient preference. Main disadvantages are its lower sensitivity for detection of early glaucomatous visual field loss and its greater susceptibility to patient response errors.

Blue on Yellow Perimetry (Short Wave Length Automated Perimetry)

Adoption of colour perimetry to automated perimetry consists of a high luminance, yellow background field and a large (size V) short wave length (blue) test stimulus.

Blue-on-yellow perimetry can detect early changes in glaucoma. The major disadvantage is that the transmission property of the lens must be measured to distinguish short wavelength sensitivity losses that are caused by neural losses in glaucoma.

Flicker and Temporal Modulation Perimetry

Reduced sensitivity to flicker and temporal modulation of stimuli has been reported in ocular hypertensive patients and glaucoma patients.

Pattern Discrimination Perimetry

This procedure requires the detection of an alternating checker board pattern of dots on a background of dynamic random dots.

Visibility of the stimulus is varied by changing the percentage of dots. The rationale underlying this test procedure is that pattern discrimination requires a greater amount of interaction among ganglion cells than for simple detection of light. So, it may be more sensitive to early glaucomatous damage and ganglion cells.

INTERPRETATION OF AUTOMATED PERIMETRY

Before interprating automated visual fields we must know the options available when performing these tests. The test locations can be as close

together as 1° and as far apart as 6°. The tests can examine the central 10°, 24° or 30° and can also include the peripheral 30° or 60°. The test locations can either straddle the horizontal and vertical midlines or fall exactly on these midlines. In test choice the options usually involve a trade off of more informations for increasing test time and patient fatigue. In most standard situations a reasonable compromise is to test the central 24° or 30° with a 6° grid. This will miss about 11 per cent of patients with glaucoma in whom an isolated peripheral defect is the first and only sign of the disease. In testing for glaucoma the -2 tests, which straddle the midlines, provide the most information since the disease also respects the horizontal midline.

The test can be performed using suprathreshold or threshold techniques. Threshold techniques are more time-consuming but are necessary for accurate diagnosis and follow up of glaucoma patients. Newer strategies for threshold testing, such as fast pac, may save test time with minimum loss of accuracy though it can miss minor defects.

Interpretation Guidelines
Diagnosis
1. Check the patient demographics.
2. Check the reliability measures.
3. Assess the probability plots. Is the defect generalised or localised?
4. Check the global indices.
5. Check the hemifield test results.

Progression
1. Verify that the correct baseline was selected.
2. Determine which points have changed.
3. Determine whether the change is clinically relevant.
4. Determine the basis for the change.
5. Confirm the change with repeat testing.

Interpretations
Parameters
1. *Test parameter* Central 30-2 and 24-2 are the standard programmes. In presence of cataract, poor vision from other causes, advanced glaucoma, etc. appropriate alternative programme with larger stimuli or greater resolution is advocated. Normally use of nonstandard parameter will result in nonavailability of statistical comparison. However, nonstandard parameters are essential in the presence of other anomalies like cataract.
2. *Optically dilated pupil* It is essential to avoid false-positive field defects. Small pupils (smaller than 2.5 mm) may cause decreased sensitivity, particularly when associated with lental opacity.
3. *Appropriate refractive near correction* It is needed for proper field charting.
4. *Reliability parameters* False-positive errors indicate over enthusiastic patient and the field charted is better than the actual field. False-negative errors indicate inattentive patient and they may be acceptable in the presence of large field defects. Fixation losses indicate improper fixation. Because of the effect of learning curve, despite good reliability parameters, first field should not warrent major therapeutic decisions.

Interpretation of Results
1. Without statpac and non-standard parameters.
   i. Gray scale provides an overall impression of the field. It could be misleading in early field loss.
   ii. Depth of defect highlights points which are more than 5 db below normal.
   iii. Numeric values are the raw data and it is difficult to interpret them in early defects without statistical assistance.
   iv. Large fluctuations (values given in brackets) could be an indication of early defect or a location adjacent to a deep defect.
   v. The normal values are in low 30's around fixation, mid 20's beyond blind spot and high 10's in periphery.
2. Statpac I

Gray scale and numeric values These are studied as described in the earlier section.

Total deviation probability plot At each point the determined threshold is compared to the age

corrected mean value of normal population stored in the computer data base. These values are given both in number and in probability maps. These probability maps will give information about which points are abnormal and how unlikely it is to have a similar value at that point in a normal population.

Pattern deviation probability plot In the presence of a non-glaucomatous cause for diffuse loss of sensitivity as in cataract, the damage specific to glaucoma can be picked up by looking at the pattern deviation values and probability maps. It is derived by correcting the total deviation numbers by adjusting for the level of the patient's own hill of vision thus removing any deficit that are of generalised nature.

Global indices (visual field indices): Mean deviation (MD) It is a statistical summary of all the threshold determinations and gives by how much the mean threshold in the test differs from that of age matched control normal.

Pattern standard deviation (PSD) It is a numeric value giving the approximation of roughness of the hill of vision or localised scotoma.

Short-term fluctuation (SF) It is an estimation of the intra-test variability of threshold determination. It is a factor both of reliability as well as early glaucomatous damage. It is derived by repeating the threshold measurements of a number of points, usually 10, during the same testing session.

Corrected pattern standard deviation (CPSD) It is a numeric value indicating localised scotomas after correction for short-term fluctuation.

3. Statpac II

Hemifield test/glaucoma hemitest (GHT) It compares identical clustures in the superior and inferior hemifields in five areas and indicates if there is any significant difference between them. This could be an early sign of damage in some patients that is too mild to be picked up by other means. The printout reports the result as within normal limits, borderline, outside normal limits, general reduction of sensitivity or abnormally high sensitivity.

Cluster analysis Clusters involving arcuate areas are claimed to be more specific to detect early glaucomatous damage.

Blue on yellow perimetry Humphrey has introduced blue stimulus on yellow background perimetry. The damage is picked up by this method earlier than standard perimetry.

Progression of field defect: Overview print out It can print up to 16 fields in one page and has the gray scale, numeric data, total and pattern deviation plots along with the data of examination, reliability parameters and global indices.

Comparison of total and pattern deviation plots over time is an useful way of assessing progression of field defect.

Box-plot It is a histogram summarising differences between patients test points and age-matched normal. The box represents 70 per cent of the test points with the central bar indicating median value, upper tail representing positive deviations from normal and lower tail representing negative deviation from normal. Long negative tail means deep scotoma involving 15 per cent of all points. Elongated box means severe loss or many scotomas involving some 70 per cent of test points. Sinking box can mean normal shaped hill of vision but lowered median value as in cataract.

Comparison of global indices Comparison of global indices over a period of time can be a good measure of stability of visual field.

Glaucoma change probability (in Statpac II) It compares the changes among test in damaged fields to a control group of known by stable glaucomatous fields. Baseline field could be, the mean of the first two fields or any as chosen by the examiner.

Follow up examinations will show change from baseline labelled as dB from baseline showing the difference between each plot and the baseline.

The following four symbols are used in this map:

i. A black triangle—appears if a deterioration was seen at that point less than 5 per cent of the time.

ii. An open triangle—appears if an improvement was seen at that point less than 5 per cent of the time.
iii. A small dot—the value in between the two above confidence intervals.
iv. X—indicates insufficient information.

Up to 4 open and 4 closed triangles can appear in a stable glaucomatous field.

MD change analysis It compares MD of follow-up tests to glaucoma data base. Linear regression analysis is possible for less than 5 tests.

High Spatial Resolution Automated Perimetry

Conventional automated perimetry threshold examinations have a relatively low spatial resolution with 6 degrees separating adjacent test locations in the Humphrey 24-2 or 30-2 programmes. If perimetry is performed at higher resolution a more detailed picture of the luminance sensitivity in selected areas of the visual field may be obtained and thus scotomas could be investigated in much finer details with detection of subtle scotomas beyond the resolution of conventional perimetry. It can also identify scotomas that correspond to retinal nerve fibre layer defects in glaucoma suspects previously undetected by conventional perimetry. This can be achieved by using Humphrey perimeter to generate a fine matrix map (FMM) of a specified region of the visual field within an acceptable test time.

To perform fine matrix mapping perimetry the co-ordinater of four interlaced 5 x 5 grids of 25 locations (with a separation between adjacent points of 2 degrees) are entered in the 'custom grid' feature of a Humphrey automated perimeter. Each grid is off set relative to the other grids by 1 degree in the x, y, or x and y axes. The patient undergoes examination using each of the four grids sequentially, using a target size III on a standard Humphery bowl illumination of 31.5 apostilbs. Accuracy of fixation is monitored in the same way as conventional perimetry.

The data are processed to produce a single matrix with a separation between test locations of 1 degree. This fine matrix mapping of 100 locations subtends a visual angle of 9 degrees by 9 degrees, approximately the area occupied by four locations in the 30-2 programme. The numerical matrix is then used to generate a surface or coutour plot which shows the size and location of luminance sensitivity gradients across the grid.

Chapter 7

Examination of Strabismus

In order to correctly diagnose and treat a case of strabismus, the detailed examination including history taking is very much important.

HISTORY TAKING

In case of strabismus history taking should cover the following aspects:

Age of onset and the duration of strabismus These are of particular importance in cases of accommodative squints. Moreover the duration of manifest squints indicates the prognosis regarding binocular vision, which may be suppressed due to prolonged negligence.

Type of onset of strabismus It is also very important. It may be sudden, gradual or intermittent in nature.

Past history of diplopia or blurring It is very much important to enquire about any recent or past history of diplopia or blurring. Blurring may be complained by patients who are borderline cases of phorias breaking into tropias. Diplopia will be complained by the patients with recent ocular palsies, in whom, suppression of one eye has not yet developed. In case of diplopia it is necessary to find out the positions where the diplopia is minimum and maximum.

Stress conditions It is often found that stress condition like fever and other debilitating conditions precede the onset of squint. So careful medical history before onset of squint must be recorded.

Cases of strabismus Often strabismus cases are found in families, so careful family history must be recorded.

EXAMINATION OF STRABISMUS

VISUAL ACUITY

The vision must be recorded carefully, as it is necessary to detect whether any refractive error is present or not. The vision must be recorded with and without glasses. If visual acuity remains poor in spite of full refractive correction and healthy fundi, amblyopia is diagnosed.

REFRACTION

Phorias

The cases with phorias must be given proper refractive corrections. The vertical and tortional phorias are almost always accompanied with horizontal components. In exophorias, myopic corrections must be given though hypermetropic correction less than +2 D sph is not recommended. In esophorias, hypermetropic corrections must be given, particularly if it is more than +1.25 D sph but myopic corrections must be avoided.

Squints

The cases of accommodative squints may be either refractive accommodative esotropia or high AC/A accommodative esotropia.

Refractive accommodative esotropias These are cases where the mechanism is a combination of uncorrected hypermetropias and inadequate fusional divergence amplitude. Here the therapy is proper refractive correction.

i. Full retinoscopic finding plus an additional +1.50 D sph as a single vision lens should be provided in a child below 4 to 5 months of age;
ii. Any child between 4 months and 4 years with esotropia and a refractive error more than +1.50 D sph should be given the full retinoscopic findings but not additional plus;
iii. For a child of 4 years or older, minimum power lens that comprises both binocular single vision with esophoria and maximum visual acuity is provided.

High AC/A accommodative esotropias Here full retinoscopic findings +1.50 D sph should be given as a single vision lens to an infant who is less than 4 or 5 months old. The full retinoscopic findings along with a bifocal add of +3.00 D sph in both eyes, should be given to an older child up to the age of 5 years. The add should be properly located so that it bisects the pupil.

BRUCKNER'S TEST

Bruckner's test offers an assessment of eye alignment in young patients whose eye alignment may be impossible to assess using the subjective methods and whose limited co-operation and fixation prevent an accurate assessment by cover test.

Bruckner's reflex test is performed by using the direct ophthalmoscope to obtain a red reflex from both eyes simultaneously. The patient should look at the light during the test. If the patient looks to peripheral targets, the test is invalid. In patients with strabismus, this test shows asymmetric reflexes with a brighter reflex coming from the deviated eye. This will identify any pathology that changes the normal red reflex including anisometropia, gross retinal pathology, large retinal detachment and corneal, lenticular or vitreous opacities.

The child is placed in a parent's lap watching the examiner positioned about 1 metre from the child. The room illumination is dim to help focus the child's attention on the examiner's light and to aid the examiner's observation. As the test is influenced by asymmetrical refractive errors, the habitual refraction should be worn if the test is used specifically for the detection of eye misalignment. However, the sensitivity for detecting deviations of 2° or less is decreased with correction. If the patient presents without correction, the refractive error must be known before an accurate interpretation of the results can be made. Testing is done with natural pupils before dilation or cycloplegia. The examiner directs the light from a direct ophthalmoscope at the patient so that both eyes are simultaneously illuminated. Often singing, animal sounds or other unusual noises are necessary to maintain the child's attention on the light. The examiner then focuses the ophthalmoscope so that the pupil and red reflexes are in sharp focus for optimal observation. The brightness of the two red reflexes are compared. If the red reflexes are of equal brightness in the two eyes, normal eye alignment is present. The advantage of Bruckner's test is its ability to detect deviations smaller than the lower limit of the Hirshberg's test (about 5° or 10 prism dioptres). Bruckner suggested that a deviation of 1.5° (3 prism dioptres) induced an observable change in the red reflex of the deviation eye.

Common Causes for Variable Measurements

Poor control of accommodation It is important in young children and patients with a high AC/A ratio.

(*Solution* use targets that need full accommodation to be seen. Targets with small detail close to visual threshold are the best.)

Variable working distance Usually, it is near.

(*Solution* control working distance to one-third of a metre at near, and standardise working distance. This is more critical for near measurements. Have a string measured at one third of a meter to measure the near working distance).

Tonic fusion not suspended This is usually seen in fusion patients with intermittent exotropia or accommodative esotropia.

(*Solution* keep binocular vision dissociated by prolonged occlusion with alternate cover testing. Make sure one eye is always covered when changing prisms).

Physiologic redress fixation movements These are commonly associated with large angle strabismus. Even when the deviation is neutralised, there is an overshoot of the refixating eye.

(*Solution* Move occluder away from the patient's face to allow peripheral vision of the occluded eye. Also judge the point of neutralisation, as the point when the redress movement is equal to the refixation movement. Finally, bracket the deviation by intentionally overcorrecting with too much prism, then reduce prism until the best neutralisation is achieved).

Incomitant deviation (A or V pattern and lateral gaze incomitance) Small changes of face turn, head tilt, or chin elevation or chin depression during the examination will change the size of the deviation if the deviation is incomitant.

(*Solution* Control the patient's head position for primary position and cardinal fields of gaze. Consistent head positioning is critical if reproducible measurements are to be obtained).

COVER TESTS

Cover-uncover Test

This test is used to detect phorias. The patient must fix any object with one eye and the other eye should be covered by the examiner. If the cover is removed, the movement of that eye should be recorded carefully. If there is no movement of the covered eye, the phoria is absent. If there is movement of the covered eye then the phoria is present, which may be vertical (hyper or hypo), horizontal (exo or eso) or tortional (incyclo or excyclo). This test must be done both with or without glasses and for near (1/3rd metre) and for distance (6 metres) (Fig. 7.1, Plate 13).

Alternate Cover Test

This test is used to detect tropias (manifest deviations). Here, the patient fixes any target with the undeviated (good) eye, with the deviated eye being covered. When the undeviated (good) eye is quickly covered instead of the deviated eye, the deviated eye takes up fixation. Now if the cover is removed and the deviated eye remains the fixating eye, it is an alternating type of squint where both the eyes are individually capable of taking up the fixation. But if the deviated eye fails to keep fixation yielding to the undeviated (good) eye then the deviation is for one eye only, i.e. for the deviated eye (uniocular squint) (Fig. 7.2, Plate 14).

QUANTITATIVE DIAGNOSIS OF STRABISMUS

Measurement of Tropia

Hirschberg's test This test is employed to estimate the deviation of the corneal light reflex from the centre of the pupil. The fixation light is held at 1/3rd metre from the patient. 1 mm of deviation corresponds to 7^{o} of ocular deviation, i.e. if the corneal reflex falls on the pupillary margin, the deviation is 15^{o} whereas if it falls on the limbus the deviation is 45^{o} (Fig. 7.3).

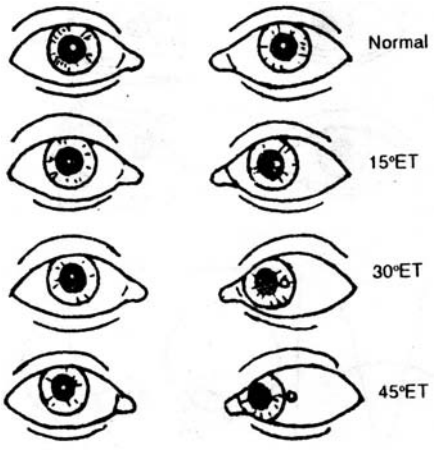


Fig. 7.3: Hirschberg's test

Prism bar reflex test (PBRT) Here the prisms of increasing strength (mounted as prism bar) are placed in front of the fixating eye, till the light reflex is centred in the deviating eye. In cases of eso-deviation base-out prisms and in cases of exo-deviations base-in prisms are used. The prism required to attain this condition is used to record the angles of deviation (Fig. 7.4).

Prism bar cover test (PBCT) After performing the prism bar reflex test, alternate cover test is done to detect whether there is any residual movement present. The point at which no movements remain is detected and the prism required to attain this condition is used to record the angle of deviation (Fig. 7.5).

Measurement of Phorias

Principle The eyes are dissociated and the binocular fusion is broken. Then measurements are taken to determine the angle of deviation.

Maddox rod test Here the eyes are dissociated by distorting one image. The test is performed at 6 metres for distance and also at 1/3rd metre (for

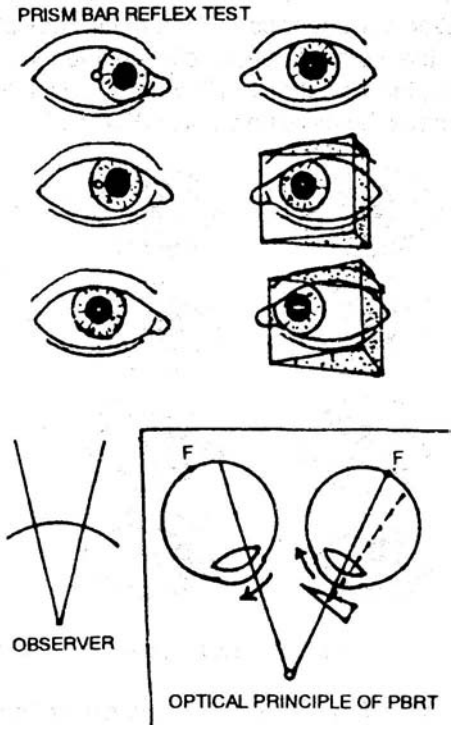


Fig. 7.4: Prism bar reflex test

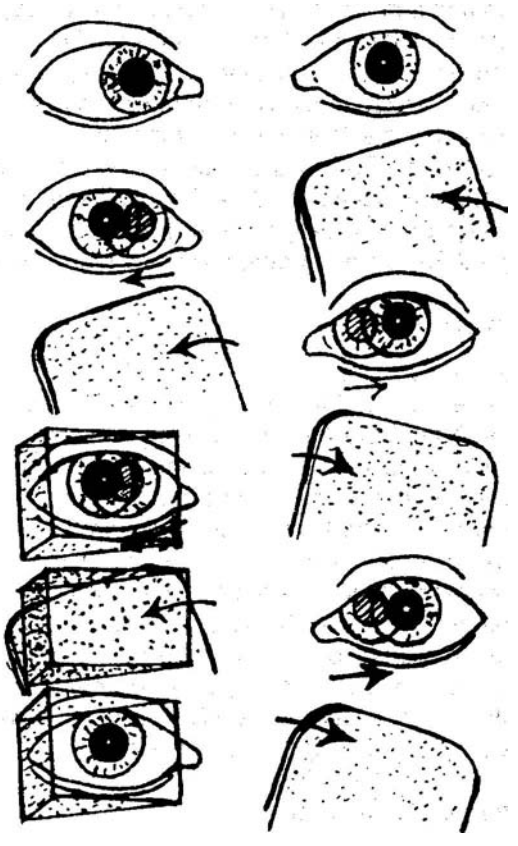


Fig. 7.5: Prism bar cover test

near). During the test the patient must wear his spectacle corrections and the vision must be sufficient to see the light with one eye and the line with the other eye (Fig. 7.6).

The only problem of this test is that it cannot differentiate between heterophorias and heterotropias with binocularity.

Method

i. *For horizontal phorias* The maddox rod is placed horizontally before the right eye. When the patient looks at the light through the maddox rod he finds a vertical red line. With the left eye he sees the light only (Fig. 7.7, Plate 14). Patient's responses are interpreted according to Table 7.1.

The degree of horizontal phoria is measured by placing a prism of suitable strength (base in/base out) which achieves perfect alignment.

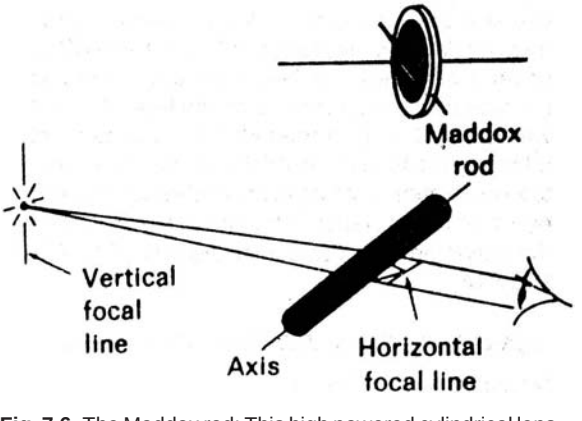


Fig. 7.6: The Maddox rod: This high powered cylindrical lens is used clinically to form a line image from a point source of light

Table 7.1: Interpretation of horizontal phorias

Response	*Interpretations*
When the red line is perfectly aligned with the light	No horizontal phoria
When the line is on the right side of the light	Crossed diplopia, i.e. exophoria
When the line is on the left side of the light	Uncrossed diplopia (homonymous), i.e. esophoria.

ii. Tortional phorias (cycle deviations) Two maddox rods (one red and one white) are placed before each eye and kept at the same angulation (i.e. both horizontally at the 180^{o} axis). The red maddox rod produced a red line whereas the white maddox rod produces a white line. If the red line and the white line make an angle between them then there is tortional/cyclophoria. The degree of rotation required to make them overlapping or horizontal measures the degree of cyclophoria (Fig. 7.8, Plate 14).

iii. For vertical phorias: The maddox rod is placed vertically before the right eye. When the patient looks at the light through the maddox rod he finds a horizontal red line. With the left eye he sees the light only (Fig. 7.9, Plate 15). Patient's responses are interpreted according to Table 7.2.

Table 7.2: Intrepretation of vertical phorias

Responses	*Interpretations*
When the red line is perfectly aligned with the light	No vertical phoria
When the line passes below the light	Left hyperphoria (or right hypophoria)
When the line passes above the light	Right hyperphoria (or left hypophoria)

(The measurement is done with base up/base down prisms.)

Maddox wing test It is a device which records the degree of heterophoria (for near) at a distance of 1/3rd metre from the eyes. The patient looks through the two slits in the eyepiece and the fields of each eye are separated by a plate. The right eye sees a white arrow pointing vertically upwards and a red arrow pointing horizontally to the left and the left eye sees a horizontal row of digits, in white and a vertical row of digits in red. These are calibrated to read in degrees of deviation (Fig. 7.10, Plate 15).

i. The horizontal phorias are measured by noting the digit which is pointed by the white arrow. If the arrow points the digits on the left hand side of '0' there is exophoria and if it points to the right hand side of '0' there is esophoria.
ii. The vertical phorias are measured by noting the digit which is pointed by the red arrow. If the red arrow points any digit above '0' there is left hyperphoria and if it points to any digit below '0' there is right hyperphoria.
iii. Tortional phorias are diagnosed if the white line and the red arrow are not parallel. The degree of rotation required to make the red arrow parallel to the white line is the measurement of degree of cyclophoria.

Prisms dissociation test A 6 Δ base down is held before one eye and a rotary prism is held before the other. In the presence of a horizontal heterophoria the patient will have vertical and horizontal diplopia. By means of the rotary prism the images are aligned horizontally until one is seen on top of the other (Fig. 7.11).

Maddox double prism test The patient views a horizontal pencil line, drawn on white sheet of paper, with the eye to be tested. In front of the other eye a double prism (two 4 Δ prisms mounted together base to base) is placed in the frame. The central line is seen by the eye to be tested and the upper and lower lines by the other eye. In the absence of cyclodeviation all the three lines are seen parallel. The central line is tilted outwards in incyclophoria and inwards in excyclophoria (Fig. 7.12).

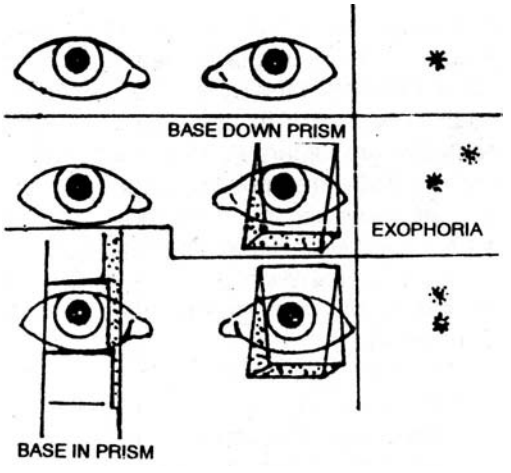


Fig. 7.11: Prism dissociation test

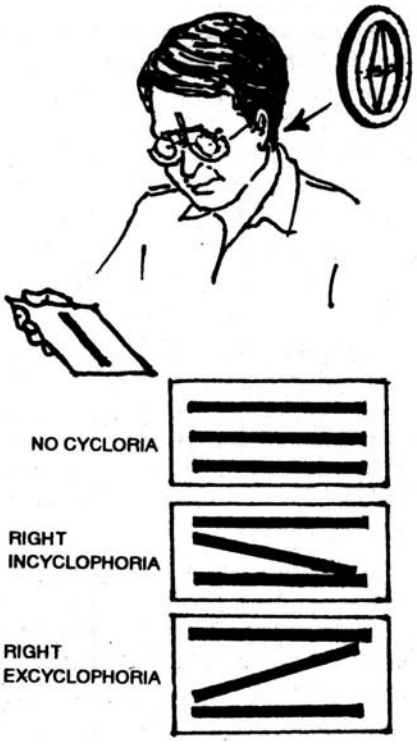


Fig. 7.12: Maddox double prism test

EVALUATION OF THE SENSORY STATE

Estimation of Visual Acuity

The recording of visual acuity in the adults is an easy test but its estimation in children is difficult. If the visual acuity is equal in both the eyes, the child will not object in having his either eye occluded. If the visual acuity is reduced in one eye the child will cry or push the occluder aside when the sound eye is covered.

The Two Pencil Test for Stereopsis

The examiner holds a pencil vertically in front of the patient. The patient is asked to touch the tip of the examiner's pencil from the above with a second pencil held by the patient. If the patient fails to touch with one eye closed whether touches with both the eyes open, it indicates that gross stereopsis is present under binocular conditions (Fig. 7.13).

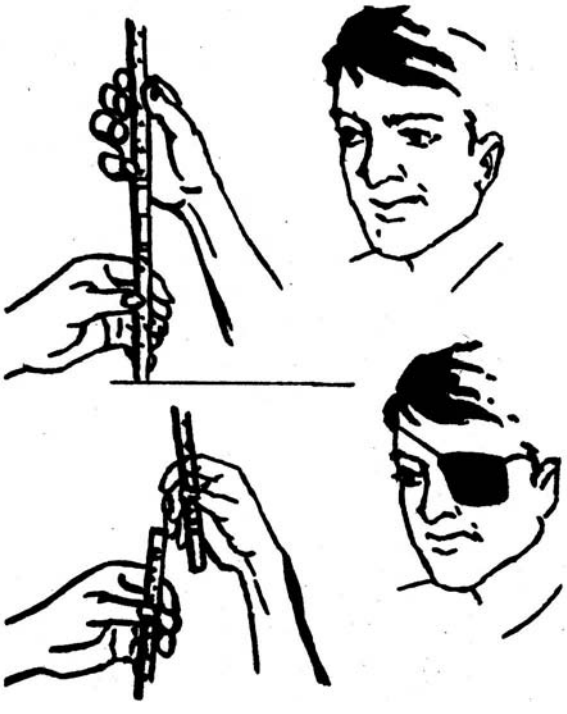


Fig. 7.13: Two pencil test from stereopsis

Titmus Fly Test

This consists of a three dimentional polaroid vectograph consisting of two plates in the form of a booklet. On the right is large fly and on the left are a series of circles and animals. The plates are viewed with polarised glasses. The 'fly' is used for testing gross stereopsis where the fly should appear in "solid" three dimensions. The 'circles'

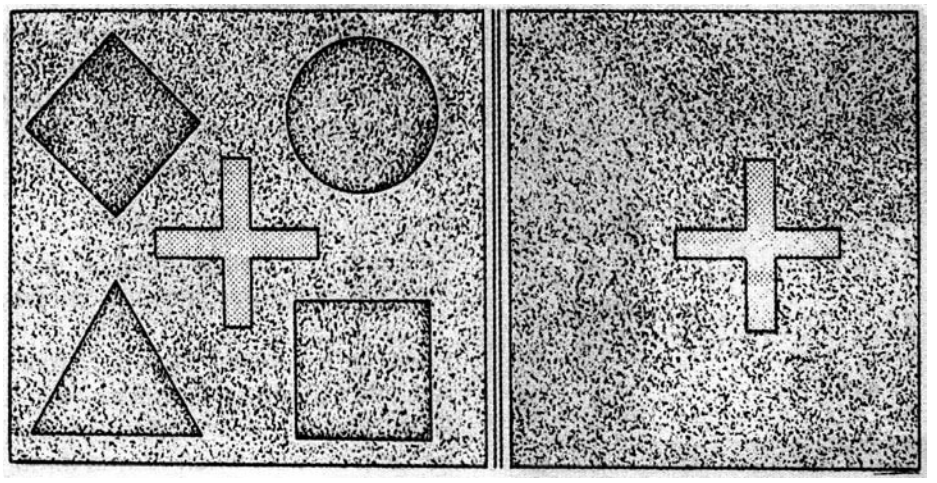


Fig. 7.15: TNO random-dot test

and 'animals' are used for fine depth perception (Fig. 7.14, Plate 15).

TNO Random-dot Test

It consists of seven plates each of which contains various shapes (squares, dots, crosses) created by random dots in complementary colours which are viewed with red-green spectacles. The plates contain both visible features which can be seen with or without the red-green goggles and hidden shapes which are visible only with red-green goggles. The first three plates enable the examiner to find out the presence of stereopsis and the other plates are used to determine its level. As there are no mono-ocular clues, the TNO test provides a true measurement of stereopsis (Fig. 7.15).

Randot Stereotest

It is a polaroid test similar to titmus stereotest but utilising a random-dot type of target instead of contour targets. It is polarised in the same way and viewed with the same kind of glasses. This test appears to be better than the titmus test in terms of giving fewer monocular clues, but does not appear to be as good as the TNO test, except in so far as the red green glasses of the TNO test tend to produce more dissociation in patients with a poorly controlled phoria, and therefore, lead to poorer results. Another version of the test consists of a random-dot letter—"E". It is performed at 50 cm and the child is required to identify which of the two plates contain the "E".

Frisby Stereotest

It is a stereotest based on actual depth of the target. It consists of three perspex sheets of different thickness and the patient is asked to identify which figure of four on each plate is the one that is either closer or farther away, the fixation target having been printed on one or the other side of the perspex sheet (Fig. 7.16). The disparities are between 600 and 15 seconds of arc and it is easy to use in relatively small children who will either look towards the disparate target or may reach out to grasp it. As glasses are not required it is an easy test to do. Its advantages are that if there is any movement of the plates or indeed of the patient's head, then it is quite easy to pick out the disparity even monocularly.

Lang Stereotests

These tests are based on the, principle of the "three-dimensional postcard". These are stout plastic cards with a ribbed surface, one set of images being printed on one slope and another

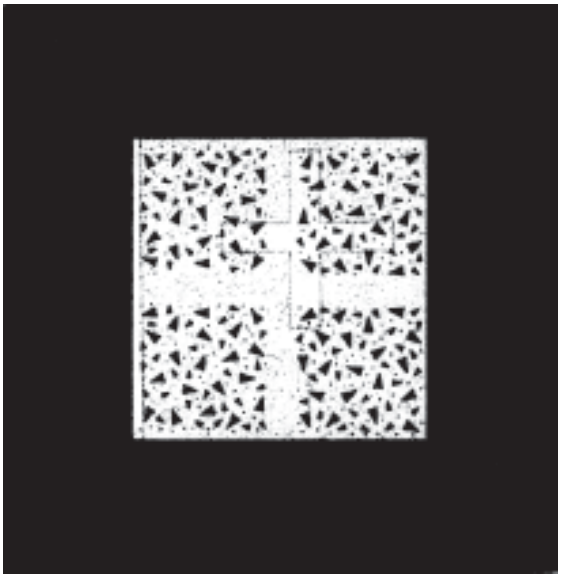


Fig. 7.16: Frisby stereotest-6 mm plate: There are 4 squares of texture, one of which contains a roughly circular 'Target' patch which, for observers with stereopsis, appears in front of 175 surround (or behind, if viewed from other side)

on the opposite slope. If they are then viewed at an appropriate working distance one eye will tend to see the lefthand side of the picture, the other eye the right. If a random-dot image is printed onto the postcard then the patient will see something standing-out from the background. On card I all the targets have stereodisparity and consist of a cat, a car and a star. On the card II there is a cresent moon, a car and an elephant, but in addition there is one target that does not have stereodisparity in which the child can identify. This is in order to encourage the child who will pick at least one of the four targets and thereby does not feel frustrated by his/her failure. It is a fairly gross test and detects stereodisparities between 1200 and 200 seconds of arc. The test is easy to do and does not require any glasses.

The disadvantages are that it is difficult to be sure what the child is grasping or reaching for. It is hard to hold the card parallel to the face without head movement and unless a verbal response is obtained it is difficult to be sure whether anything has been seen.

Awaya Stereotests

It is no longer widely available though valuable. It is based on red/green dissociation, comes with its own set of glasses and measures stereoacuities from 4120 down to 40 seconds of arc. It appears to lack of monocular clues.

Worth's Four Dot Test

This test provides information only about the status of peripheral binocular co-operation.

Principle: A red glass filters out all colours except red, and a green light is not visible through a red filter. Similarly, every colour except green will become invisible when viewed through a green filter (Fig. 7.17, Plate 15).

Looking through a pair of diplopia goggles (with red before the right eye and green before the left eye) the patient views a box with four lights (one red, two green and one white) at 6 metres and at 1/3rd metre. Patient's responses are interpreted according to Table 7.3.

Table 7.3: Interpretation of Worth's test

Responses	*Interpretations*
i. If the patient sees all 4 lights	There is peripheral fusion with orthophoria or Small angle esotropia with abnormal retinal correspondence
ii. If the patient sees 2 red lights	There is suppression of the left eye
iii. If the patient sees 3 green lights	There is suppression of the right eye
iv. If the patient sees 5 lights and	
a. The red lights to the right of green light	There is uncrossed diplopia with esotropia
b. The red lights to the left of green light	There is crossed diplopia with exotropia

There are some prerequisites for success of this test. Deep amblyopia must be absent and binocularity must be present.

The fallacy of this test may be that even when dense central suppression scotomas or small angle deviation are present, the results may indicate fusion.

4 Δ Base-out Test

Small central scotomas (1º to 2º) are difficult to detect in cases with small angles of esotropia/ microstrabismus.

Sudden displacement of an image with a 'base-out' prism from one fovea onto the parafoveal temporal retina elicits a refixation movement if the image has been shifted within a normal functioning retina but no such movements occur if it is within a nonfunctioning (scotomatous) area.

A 4 Δ base-out prism is placed quickly over one eye while the patient fixates on a point light source and the examiner observes the movement of the other eye. The test is repeated by placing the prism over the other eye (Fig. 7.18).

Fixation Behaviour Determination

The fixation is diagnosed with the visuoscope which is a modified ophthalmoscope that projects a fixation target on the fundus (Fig. 7.19). The eye not to be tested is occluded. The examiner projects the fixation target to the macula and the patient is asked to look at the black star shaped aperture. The position of the star on the patient's fundus is noted. The fixation behaviour is designated as central, parafoveal, parafoveolar or peripheral (Fig. 7.20).

Bagolini Striated Glass Test for Retinal Correspondence

The Bagolini glasses are optically plano lenses with imperceptible striations that do not blur the environment but produce a luminous stripe when a person is looking at a point light. The test is performed at 1/3rd metre and 6 metres. The glasses should be placed before the patient's eye in such a manner that the axis of striation is oriented at 135º before the right eye and at 45º before the left eye. It is advisable to eliminate all other bright light sources in the examination room during the test (Fig. 7.21).

i. In case of normal retinal correspondence there will be diplopia or suppression and there will be X response with angle corrected.
ii. In case of harmonious abnormal retinal correspondence there will be X response with manifest deviation and there may be possible central suppression or possible paradoxical diplopia.
iii. In case of unharmonious abnormal retinal correspondence there will be X response with angle partially corrected and there will be suppression or incongruous diplopia.
iv. In case of absent retinal correspondence there will be suppression or diplopia and X response will not be obtained with prism.

Synoptophore Examination
[Fig. 7.22A (Plate 15) and Fig. 7.22B].

Adjusting the synoptophore Adjustment of synoptophore is made by the following:

1. The patient's interpupillary distance is measured and the pointer is adjusted on the scale accordingly.
2. The height of the chinrest is adjusted by means of control.
3. The projection of the chinrest is adjusted by sliding it and the patient's eyes are adjusted as close to the eyepiece as possible.
4. The projection of the forehead rest is adjusted.
5. All the pointers are set at zero
   i. pointers on horizontal deviation scales.
   ii. pointers on vertical deviation scales.
   iii. pointers on tortional scales.
   iv. pointers on elevation depression scales.

USES

Assessment of Binocular Vision

When the corneal reflexes are at the centres and when there are no movement of the eyeballs on alternate illumination of the eyes by the synoptophore lights the binocularity of the eyes are determined by simultaneous macular perception (SMP)/simultaneous paramacular perception (SPMP) slides. If the person can recognise both

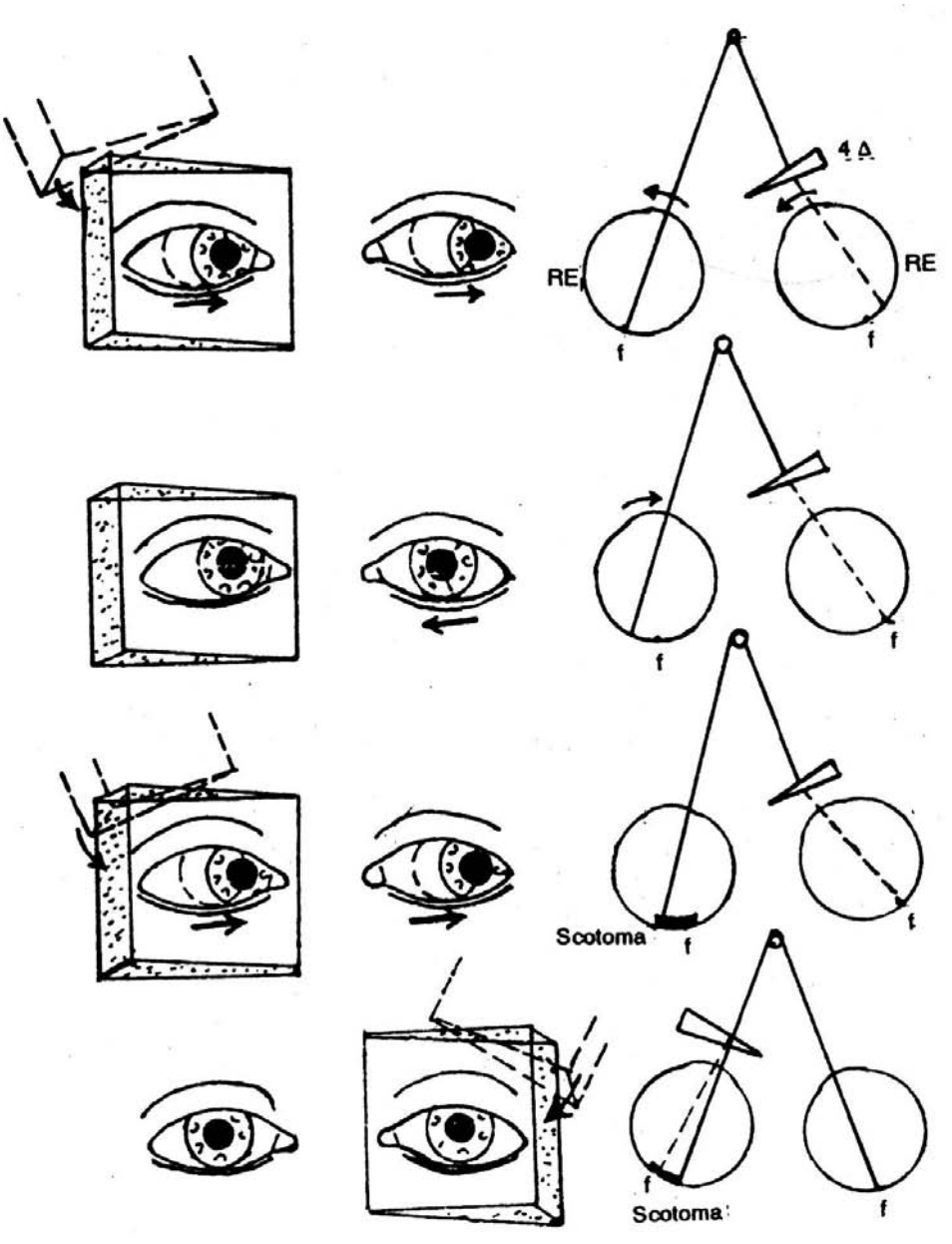


Fig. 7.18: 4Δ base-out prism test

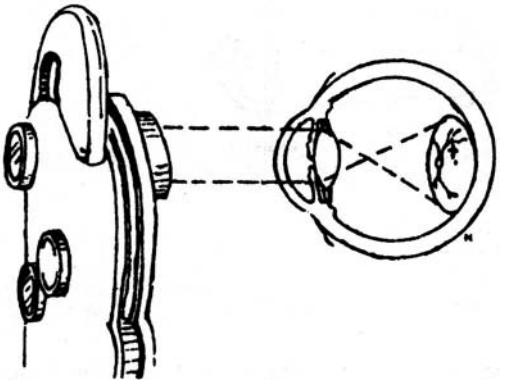


Fig. 7.19: Visuoscope

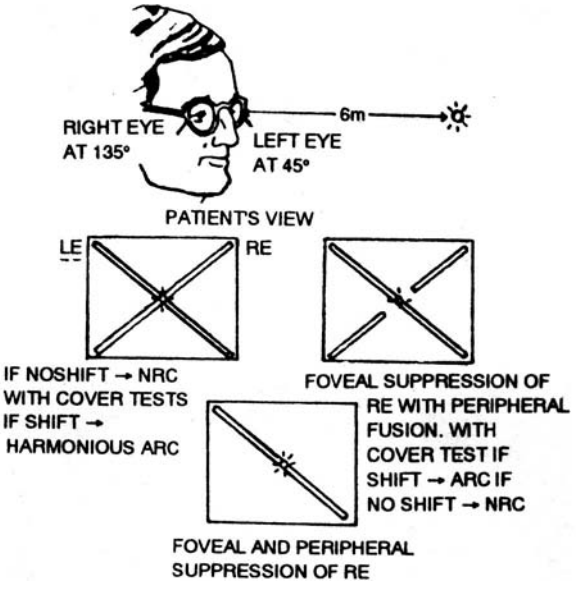


Fig. 7.21: Bagolini striated glass test

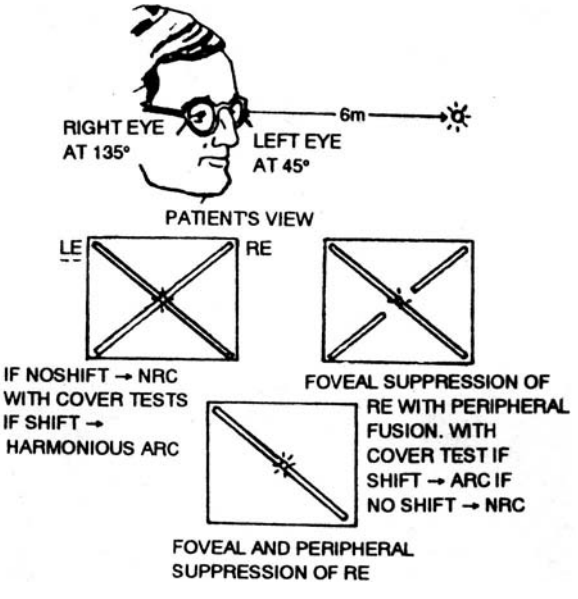


Fig. 7.20: Fixation patterns

the slides at the same time then SMP/SPMP will be present. Then fusion slides and stereopsis slides are used one after another to determine the grade of binocularity present (Fig. 7.23).

Measurement of the Angle of Deviation

The objective angle of deviation is measured with each eye fixing in turn to a pair of SMP slides. One of the lights is extinguished by depressing one of the two flashing switches and the patient is asked to concentrate on the illuminated picture. After ensuring that the fixation is accurate, the light for that side is extinguished while simultaneously switching on the other. The nonfixing eye is then observed as it moves to take up position and the movement is compensated by adjusting the horizontal and vertical controls until there is no movement of the nonfixing eye when it takes up position. The angle thus measured is the objective angle and if the fixation is central the corneal reflections are observed to be in the centres of the pupils.

The subjective angle is measured by asking the patient to move the handles and adjust the vertical control until the two pictures are superimposed. If the objective and subjective angles are equal then the retinal correspondence is normal. If the two angles differ, then the correspondence is abnormal and the difference between these two is the angle of anomaly.

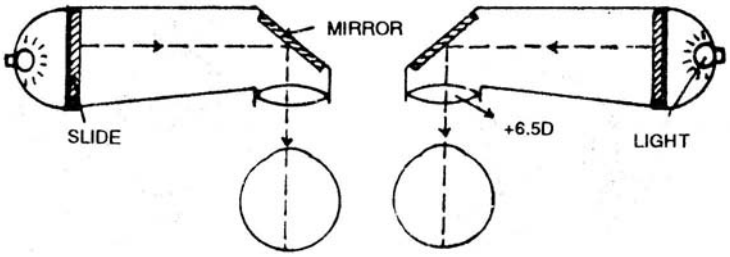


Fig. 7.22B: The synoptophore

Fig. 7.23: Assessment of binocular vision

The elevation/depression controls are used for measuring the angle of deviation in different vertical directions of gaze. The tubes can be rotated upwards or downwards to the extent of 30° although beyond 15° elevation or depression is rarely required.

Measurement of Vergences (range of fusion)
Adduction and abduction can be measured by setting the tubes at the angle of deviation and by asking the patient to fix at pair of fusion slides. The tubes are locked and the knobs for vergence control are rotated up to a point when fusion 'breaks'. Vertical vergences can be measured by rotating the elevation and depression controls.

After Images
High intensity 12 V illumination is required to create the after image. Slides for after image consist of a white vertical slit with a black background and with a red central fixation dot before one eye and a white horizontal slit with a similar fixation dot before the other eye. These slides are inserted into the carriers with the matt surface out of the optical pathway by rotating the control levers. This allows more light to pass through the slide and thus a strong after image is produced. The selector switch is rotated clockwise from the 'normal' to the first position marked `right eye'. The patient is instructed to fix on the red spot for 10 seconds with the right eye. The selector switch is turned clockwise to the next position 'change' which is the 'off' position. Right slide is removed and the diffusing screen raised again. The selector switch is moved to the next position 'left eye' when the patient fixes with the left eye for a similar period. The selector switch is then moved to 'off' position, the left slide is removed and the swivel screen is raised. Automatic flushing is then employed to enhance the after change, The selector switch is rotated to 'both eyes' and the autoflash switch is switched on. When the retinal correspondence is normal the patient will observe the after image as a +. If it is abnormal the after image will be seen as in Figure 7.24.

Haidinger Brushes
This phenomenon is caused by polarised light falling on the macula. Since the centre of the brush coincides with the fovea this effect is employed in cases of eccentric fixation and abnormal retinal correspondence.

The motorised units of Haidinger brush are fitted into the slots adjacent to the slide carrier. HB

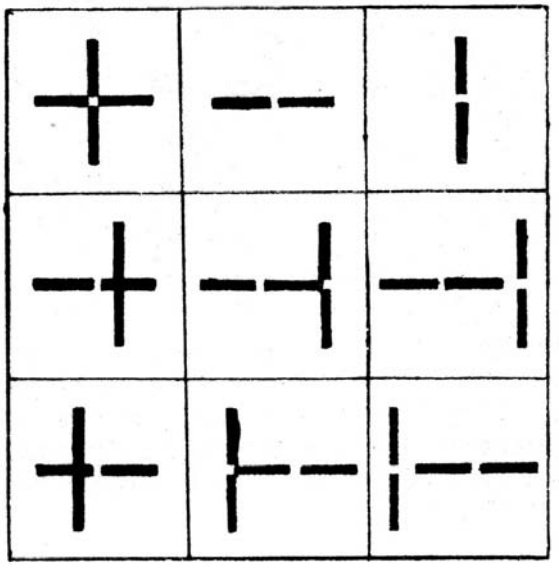


Fig. 7.24: After image key chart

lights are switched 'on' and the motor switch when lowered, rotates the polaroid discs.

In the eyepieces blue filters are incorporated in the grooves (Fig. 7.25, Plate 16).

EVALUATION OF THE MOTOR STATE

Ocular Movements
Including A and V Patterns

Ocular movements, combined with cover test, are examined in the nine positions of gaze. The patient fixes a light. Any underactions and overactions, updrifts and downdrifts are noted, looking for the maximum limitation of movements, and therefore, the affected muscles/nerves (Fig. 7.26).

For A and V patterns, prism cover test is performed at near fixation on an accommodative target with the patient wearing his full correction and the eyes in 25° elevation, primary position and 35° depression. The deviations in each positions are recorded (Fig. 7.27).

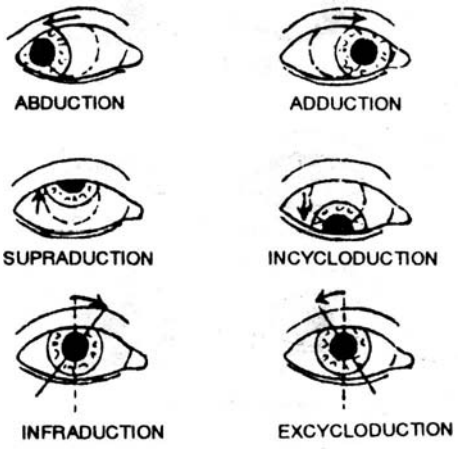


Fig. 7.26: Ductions (right eye)

Forced Duction Tests

It helps to differentiate whether an anomaly of ocular motility is caused by mechanical factors such as contracture or fibrosis of a muscle, tightness of a muscle following excessive resection and shrinkage or scarring of conjunctiva or Tenon's capsule.

This test should be performed before, during and at the completion of squint surgery.

The eye is grasped near the limbus with forceps and moved in the opposite direction that in which the mechanical restriction is suspected. This test can be done under general or topical anaesthesia (Fig. 7.28).

Abnormal Head Postures

In paralytic squints, to avoid diplopia, the patient assumes an abnormal head posture in order to achieve the position where diplopia is minimum or absent. The muscle thus affected can be located by the abnormal head posture adopted by the patient (Figs 7.29 and 7.30).

Prism Bar Cover Test in
Diagnostic Positions of Gaze

For the quantitative measurement of the amount of deviation in the field of action of each of the extraocular muscles, the prism cover test is performed in the nine diagnostic positions. The test

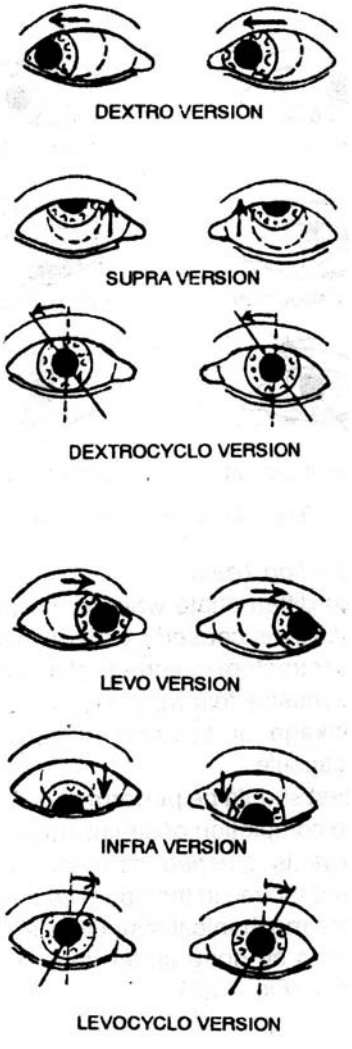


Fig. 7.27: Versions

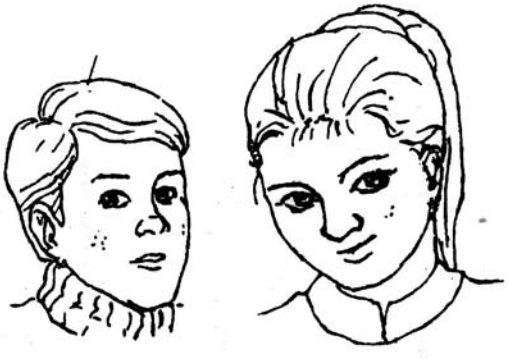


Fig. 7.29: Abnormal head postures

must be performed with each eye fixating in the turn. If the amount of vertical deviation changes depending on which eye is fixating, the affected eye is easily recognised. The maximum deviation will be in the field of the affected muscles (Fig. 7.31, Plate 16).

Diplopia Tests

The patient may wear a red and green goggles. This test is combined with ocular movements. The patients looks at a light in the nine positions of gaze (as in ocular movements) and is asked to describe the relationship of the diplopia images to each other, i.e. whether separations are horizontal or vertical or both. The patient is asked to indicate where the separation of the image is greatest and also whether, at any point, he sees single. He may also complain of tortional (tilted images) diplopia. This is likely to occur with a palsy of an oblique muscle. In such a case a bar light should

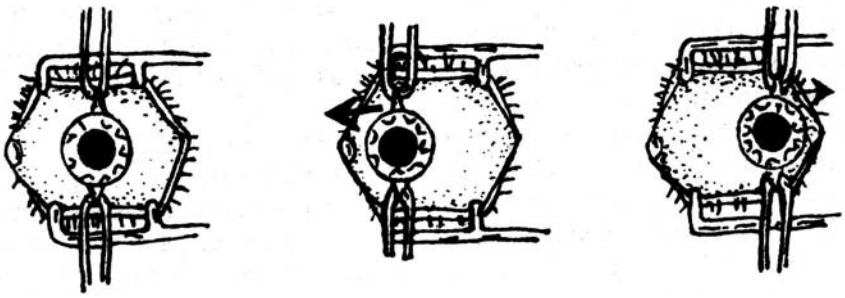


Fig. 7.28: Forced duction test

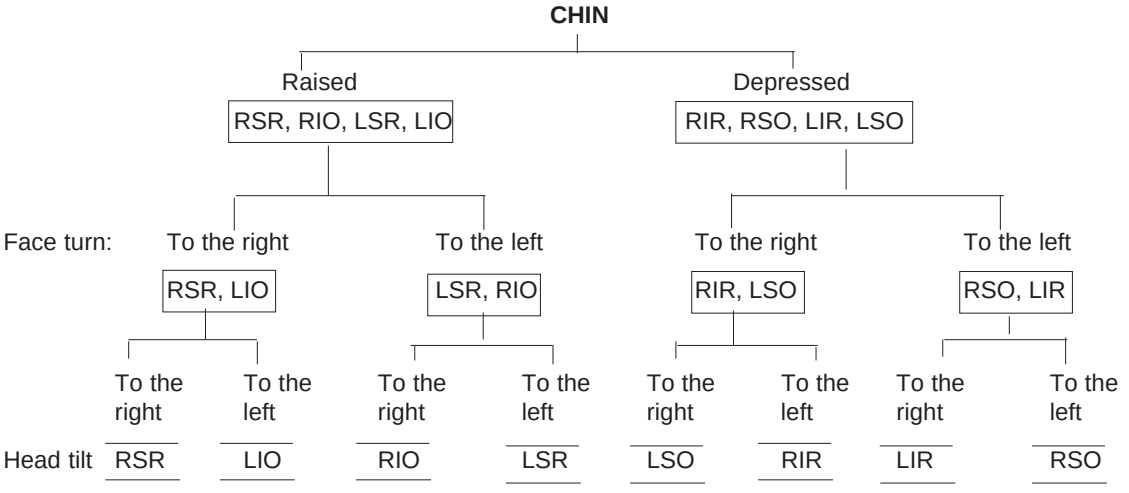


Fig. 7.30: The chart showing abnormal head posture

be used and the patient must describe which way one or both of the lines of the light are tilted, indicating an intorted or extorted image. Diplopia can be recorded either on a chart or by verbal description (Fig. 7.32, Plate 16, and Fig. 7.33).

Bielchowsky Head Tilt Test
This is a three step test:

First step This step is to find out whether there is right over left or left over right (Fig. 7.34A).

If there is right over left then the affected muscle is either the right eye depressors (RSO or RIR) or the left eye elevators (LIO or LSR). If there is left over right then the affected muscle is either, the right eye elevators (RSR or RIO) or the left eye depressors (LIR or LSO).

Second step This step is to find out whether the hypertropia is larger on right or left gaze.

If hypertropia is more on right gaze then it indicates that the right gaze vertical acting muscles are weak (RSR, RIR work vertically in abduction and LIO, LSO work vertical in adduction) (Fig. 7.34B). If the hypertropia is more on the left gaze then the left gaze vertically acting muscles are weak (LSR, LIR and RIO, RSO).

After second step only two muscles are left as possible offenders. There is always one from each eye, one is an oblique and the other is as rectus muscle, but both are either intorter (superior muscles) or extorters (inferior muscles).

Third step This step to find out whether the hypertropia is larger when measured during head tilt to the right or left? Proper measurement requires holding the base of the prism parallel to the floor of the orbit. The right head tilt torters are the RSO, RSR, LIO and LIR. The left head tilt torters are the RIO, RIR, LSO and LSR. These two muscle pairs would be circled leaving only one muscle with the three circles around it when the circles are superimposed. This is the palsied muscle.

Hess Screen/Lees Screen Test
A Hess chart is plotted using a Hess or Lees screen. This is a very useful aid for diagnosis and is plotted at every visit to record any change in the state of the palsy, and therefore, gives a valuable permanent record. The chart is recorded fixing either eye and shows the deviations in the primary position and the stage in the development of the muscles sequelae. The more recent the onset, the more incomitant the deviation will be; as there will be least muscle sequelae. If the palsy is of longer standing, the muscle sequelae will be more fully developed and it may not be possible

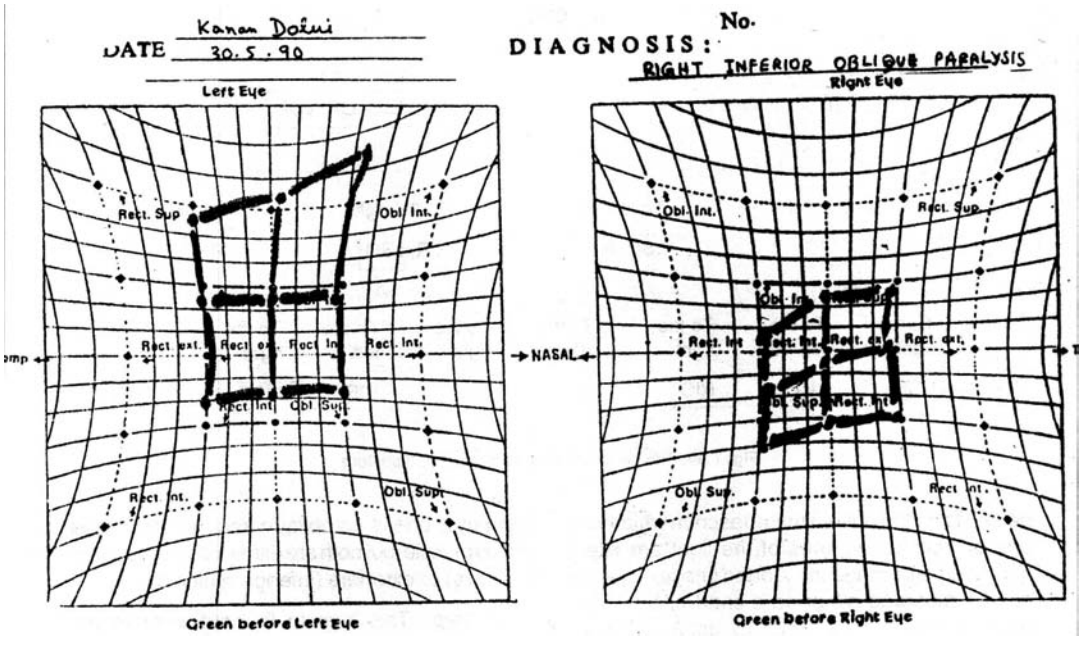


Fig. 7.33: Diagnosis of right inferior oblique paralysis

to diagnose the primarily affected muscle (Figs 7.35 and 7.36, Plate 17).

By means of dissociation (red-green glass filters or mirrors) it is possible to show the position of the nonfixing eye when the other eye is fixing, in specified positions of gaze. A field is plotted in this way for each eye. Each point on the inner field represents fixation 15° from the primary position, and on the other field, at 30°. Conventionally, the green filter is kept before the eye to be tested. With the other eye with red filter in front of it he fixes the red light on the Hess screen and with a green light (streak) he tries to superimpose it on the red spot. Thus the nine points are plotted on the chart. The patient sits at about 1/2 metres from the screen.

INTERPRETATION

Size of the fields A difference in size shows incomitance. The smaller field indicates the primarily affected eye. Equal size shows concomitance, suggesting a long-standing deviation or a nonparetic etiology.

Sloping sides of the fields: This shows an 'A' or 'V' pattern in which the horizontal deviation becomes relatively more convergent on elevation or depression respectively. This usually implies an underlying bilateral defect of ocular motility.

Examination of the smaller field This is as follows:

i. The type of deviation in primary position indicates primary deviation.
ii. The position of the greatest restriction of the field indicates the position of the main limitation of movement.
iii. The overactions are indicated by enlargement of the field.

Examination of the larger field This is as follow:

i. The type of deviation in primary position indicates the secondary deviation.

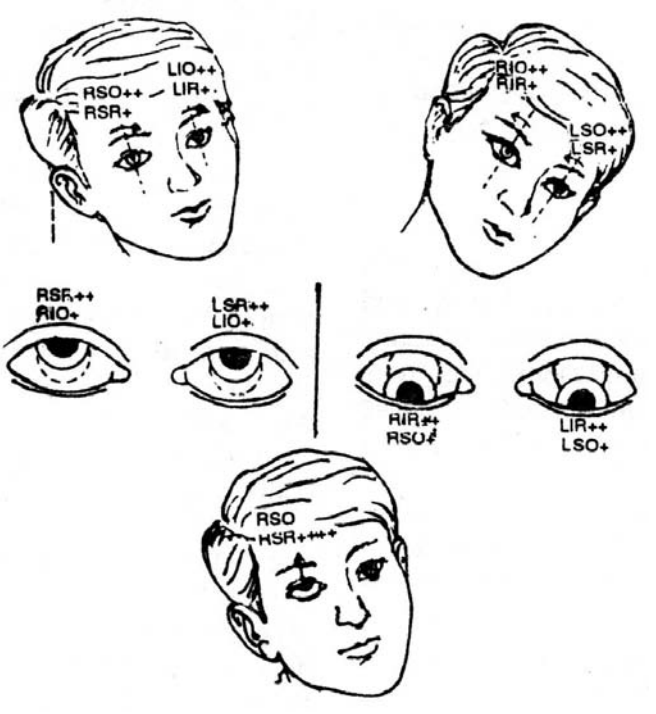


Fig. 7.34A: Bielchowsky head tilt test

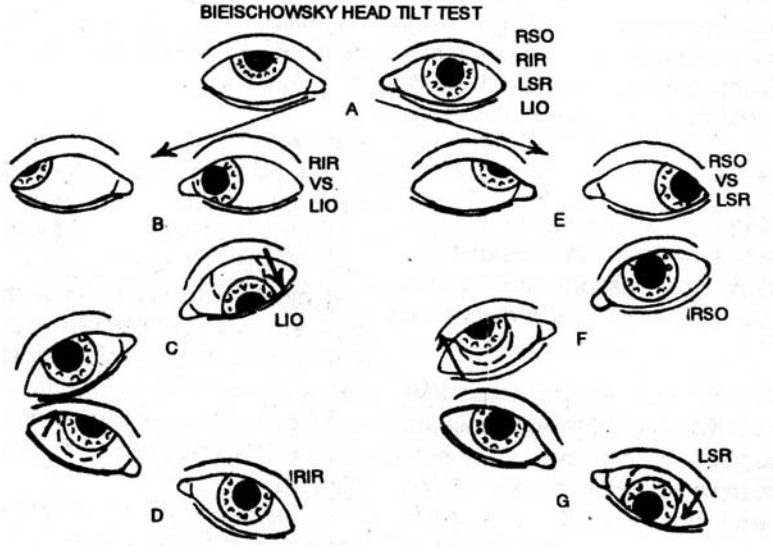


Fig. 7.34B: Diagnosis of paretic muscle in patients with right hypertropia

ii. The position of the greatest enlargement of the field shows the main overaction.

Examination of the outer fields: The outer field must always be plotted and may show a defect when the central fields appear normal, particularly where a mechanical defect is present, or in cases of slight paresis.

AC/A RATIO

This is a relationship between accommodative convergence measured in prism dioptres and accommodation measured in dioptric spheres. For each dioptre of accommodation exerted there is an accompanying amount of accommodative convergence. The normal AC/A ratio varies between 3-5 :1.

When the AC/A ratio is low, accommodative convergence is exerted resulting in near exo- or distance eso-deviations. When the AC/A ratio is high more accommodative convergence is exerted resulting in covergence excess eso- or distance simulated exo-deviations.

MEASUREMENTS

Heterophoria method In this method deviation (in prism dioptre) is measured by PBCT both for distance (6 metres) and at near (1/3rd metre). The pupillary distance is also measured. AC/A ratio is then computed from the following equation:

$$AC/A = PD + \frac{\Delta_n - \Delta_0}{D}$$

(PD = interpupillary distance in centimetres; Δ_n = deviations at near; Δ_0 = deviation at distance).

By convention eso-deviations are given a plus (+) sign and exo-deviations are given a minus (–) sign.

Lens gradient method Here the accommodative stimulus is produced adding ophthalmic lenses of the same power before each eye (+3 D sph) rather than by changing the fixation distance. The fixation distance can be taken at any point, but to minimise proximal convergence, a distant 6 metres target is recommended. The following formula is used:

$$AC/A = \frac{\Delta_n - \Delta_0}{D}$$

(Δ_0 = deviation measured without the added lens, i.e. with accommodation; Δ_n = deviation with the added lenses, i.e. without accommodation; D = power of lenses in dioptres.)

RAF Near Point Rule-Measurement of Convergence and Accommodation

Convergence is measured on the RAF near point rule. The patient is asked to indicate when an approaching fixation line becomes double (subjective convergence having failed). The examiner should watch the eyes carefully to make an objective recording because if he has suppression the patient may not notice the diplopia when convergence fails.

Accommodation is also measured by the RAF rule. Still using the RAF near point rule, the patient reports the moment when an approaching block of print becomes too blurred to read (accommodation having failed). If the monocular accommodation is normal but the binocular poor, it is the convergence which is at fault, but if the monocular and binocular readings are both poor, the accommodation is defective. Accommodation should be checked binocularly and then monocularly, each test repeated three times to be sure that it does not fatigue.

Botulinum Toxin as a Diagnostic Tool

By using Botulinum toxin chemodenervation, one can temporarily reduce or correct a misalignment of the eyes in order to determine whether the patient will be able to adapt to surgical realignment. For example after a severe head injury, a patient may have central disruption of fusion. If the eyes are then surgically aligned the patient would not be able to fuse the two images. By using botulinum toxin one can predict this outcome and avoid surgery which may lead to intolerable diplopia.

A second example of the valuable use of botulinum toxin as a diagnostic tool would be those patients with long-standing strabismus in whom one can predict postoperative diplopia if

the angle were to be either fully corrected, or over corrected. For example, a person with esotropia may experience diplopia if fully aligned, but may have no diplopia if left slightly esotropic. By using botulinum toxin, one can allow the patient to experience the new eye position and if they do have diplopia, they can determine whether they can ignore the second image or not. If they have intolerable diplopia, this will disappear as the temporary effect of the botulinum toxin test wears off.

A third example would be following a 6th nerve palsy, when one wishes to find out if the patient has a total palsy or a partial paresis. This is especially useful when the 6th nerve weakness is combined with a contracture of the medial rectus. With botulinum one can release the medial rectus contracture, and thereafter, find out if there is some function of the lateral rectus. If the lateral rectus has any function at all, the eso-deviation can be treated by recessing the medial and resecting the lateral rectus. However, if there is no lateral rectus function whatsoever, a transposition procedure is required.

So from the diagnostic point of view, botulinum toxin permits the patient to experience a temporary new eye position without resorting to surgery. Depending on the patient's subjective response appropriate surgery can then be performed, or avoided.

CAM Vision Stimulator

This treatment of amblyopia is based on the concept of active and controlled stimulation of the eye for a brief period, using spatially and orientationally simple stimuli which the patient is forced to observe by drawing on the overlying plate. All-day positive occlusion is thus replaced by a brief seven minute period of active stimulation during which the normal eye is occluded. The CAM vision stimulator has been designed to activate as many as visual cortex cells as possible by using high contrast sharp-edged, repetitive patterns (square wave grating) of different sizes (spatial frequency) slowly moving through all orientations. The CAM vision stimulator is designed to stimulate all those cells which respond to stripes of different orientation.

The motor of the CAM vision stimulator drives a turntable at speed of one RPM on which one of a series of discs bearing pattern of spatial frequency gratings is placed. A holder, over this turntable, permits a transparent plate to be placed parallel and close to the rotating disc. This plate may be drawn upon which coloured pens or pencils or plates bearing a design already drawn may be used.

The patient's normal eye is covered and he is shown the large square wave grating discs which fit on the CAM instrument. The widest stripes are presented first and treatment is commenced using the disc with the finest stripes the patient can see. The patient is now seated in front of the apparatus and is asked to draw or play games on the perspex plate, with the clinician or another patient whilst the disc is rotated under the plate. If possible two patients matched for age and intelligence should play together, as they tend to concentrate better under these circumstances.

The disc is rotated for one or two minutes and the next finer grating is placed on the spindle and the game recommended. Initially a treatment should last for seven minutes and during this time all the narrowest gratings than the one the patient started should be used then the treatment would consist of one minute on the coarsest and two minutes each on the other two.

The treatments are repeated at intervals which can be as short as daily or as long as monthly but if daily, the treatment must still be given under clinical supervision. It is usual to do the treatments frequently initially and lengthen the intervals between treatments as visual acuity improved. Treatment is discontinued if no further improvement of visual acuity occurs on three successive attempts. Those who respond well to this treatment usually do so within the first two or three treatments.

Chapter 8

Examination of Neuro-ophthalmic Cases

HISTORY TAKING

It is much important in neuro-ophthalmic cases.

The chief complaint must be carefully noted. Usually there are visual disturbances (acuity and field), diplopia, sensory disturbances (like headache and numbness) and proptosis. The history taking must include the duration and onset of first symptoms, the rate of progression of the problem, associated general signs and symptoms, past surgical, medical, drug and addiction history, family history and any history suggestive of allergies.

EXAMINATION OF THE CASES

GENERAL APPEARANCE OF THE PATIENT

General appearance of the head and face indicates the presence of hydrocephalus, microcephaly, craniostenosis, myopathies, immobility of Parkinson's disease, dry indurated skin of hypothyroidism, the contour of the face and limbs of acromegaly, etc. Compensatory head posture and face turn, if any, must also be noted.

Gait is also significant for diagnosis as in basal ganglia lesions, parkinsonism, myopathies, cerebellar diseases, etc.

GENERAL EXAMINATION OF THE EYES

Proptosis, enophthalmos, ptosis, lid retraction, squint, any fullness over the periorbital region must be noted. Normally palpebral fissure measures about 9 to 12 mm from the upper lid margin to lower lid margin. The upper lid normally covers the corneal limbus for about 1 to 2 mm. The lower eyelid touches just over the lower corneal limbus.

Rate of blinking (normal 8 to 22 minute) increases in anxiety and hyperthyroidism and reduces in facial palsy, and parkinsonism.

EXAMINATION OF VISUAL DISTURBANCE

Recording of Visual Acuity of both the Eyes

If there is uniocular disturbance then the lesion is in the eyeball or in the optic nerve whereas in bilateral disturbances the problem may be due to bilateral ocular or optic nerve disease or lesions at the chiasma or beyond.

It also must be noted whether the visual loss is gradual or sudden to differentiate a compressive lesions from an inflammatory or vascular lesion. The visual acuity should be determined to the best corrected level. Thus complete refraction should be done in every case. Often we get patients, missing letters on either side of the Snellen's chart (in hemianopia), skipping a line or missing a central letter in a chart (in scotomas).

Visual acuity (after full refractive correction) through a pin hole (1 mm in diameter) must also be noted. If visual acuity increases with pin hole then there is some refractive error present, whereas if it worsens with the pin hole there is every possibility of a central scotoma or an opacity in the media (lental/vitreous opacities). If the vision is decreased following tests must be done (1) light—brightness comparison, (2) colour perception comparison, (3) light stress recovery time, (4) afferent pupillary defect test (swinging flash light test), (5) VEP, (6) ophthalmoscopy of optic disc for pallor, oedema, cupping, and drusen.

Colour Vision Test

In disease of the retina, there may be a disturbance of colour appreciation and this is usually in the

yellow-blue or violet-blue-green area. Diseases of the conductive layers of the retina or optic nerve may lead to impairment of the red-green appreciation. Significant defect in colour vision indicates diffuse optic nerve involvement caused by compression or demyelination. *But patients with vascular lesions of optic nerve have normal colour perception though the visual acuity/fields are reduced.*

Colour vision testing is done by specialised colour plates. Pseudoisochromatic plates such as Ishihara's plates are often used for screening but are not entirely satisfactory for classification of patients with neurological diseases and may give false-positives (Figs 8.1A and B, Plate 17).

The Farnsworth-Munsell 100 Hue test is useful for comparative or serial studies. The patient is given 85 coloured caps placed in four groups and asked to arrange them in a series. Normal subjects show after 65 years of age some deterioration. Comparison of the two eyes and modification of the test have improved the accuracy and shortened the procedure. The Farnsworth dichotomous colour test panel D15 is an abbreviated version of the test. Despite all these modifications, the method does not always clarify red-green defects and gives no indications of the degree of anomaly. A new method of colorimetry is based on chromaticity circle of Newton and provided by illuminations of red, blue, and green filters balanced with a neutral density filter. This gives a white centre to a coloured circle. The area of white is recorded with a mechanical device. The test can be performed in less than 5 minutes and compares favourably with other methods.

Photostress Test (ligh stress recovery time)
This test is used to differentiate optic nerve pathology from macular pathology.

The patient is asked to look directly into an illuminated hand light held 2-3 cm away from the eye to be tested for a period of 10 seconds. Now the patient is asked to read the vision chart again. With optic nerve disease, the recovery time is not prolonged (less than 60 seconds) whereas with macular lesion, the recovery time may be 2-3 minutes or longer.

Field of Vision
Methods of recording have been *described in detail in Chapter 6.* Field testing should be done in the following cases:

a. unexplained defective vision.
b. when a patient complains of defective field of vision.
c. any signs of increased intracranial pressure.
d. any case of suspected sellar lesion.

Common field defect in lesions of visual pathway
These are described in Figure 8.2.

Visual field defects These are as follow:
Blind spot: Enlarges in papilloedema. Lesions around the disc may also cause the blind spot to appear enlarged (Fig. 8.3).

Arcuate scotomas: Interruption of a nerve fibre bundle causes arcuate scotomas (Figs 8.4A and B). Causes of arcuate scotoma are described in Table 8.1.

Table 8.1: Causes of arcuate scotomas

At disc	*Anterior optic nerve*	*Posterior optic nerve or chiasma*
Juxtapapillary choroiditis	Ischaemic infarct	Meningioma of optic canal or dorsum sellae
Myopia and peripapillary atrophy	Cartoid/ ophthalmic artery occlusion	
Coloboma	Arteritis	Pituitary adenoma
Drusen	Optic neuritis	Optochiasmal
Papilloedema	Electric shock	arachnoiditis.
Secondary opticatrophy	Exophthalmos.	
Papillitis		
Plaque in retinal artery		
Hypertensions + papilloedema		
Occlusion of central retinal artery		
Glaucoma		

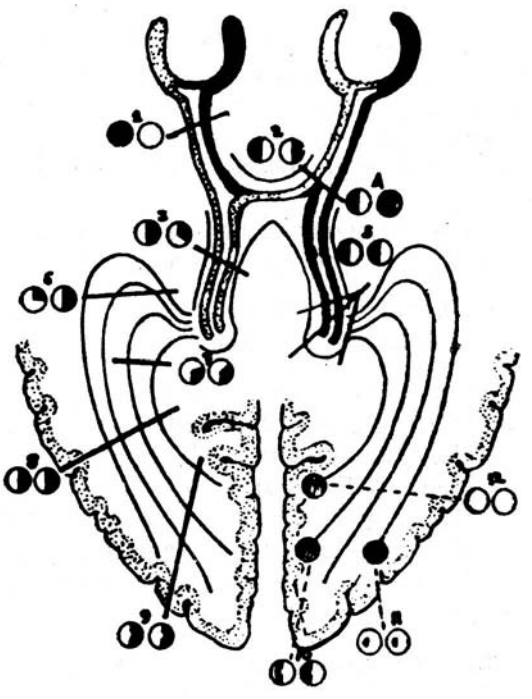


Fig. 8.2: Visual pathway with probable sites of lesion

1. Optic nerve lesions	Blindness on the side of the lesion (ipsilateral) *Normal contralateral field*
2. Chiasmal lesions	Bitemporal hemianopia
3. Optic tract lesions	Contralateral incongruous homonymous hemianopia
4. Optic nerve-chiasmal junctional lesions	Blindness on side of lesion with contralateral temporal hemianopsia or hemianoptic scotoma
5. Posterior optic tract, external geniculate ganglion, posterior limb of internal capsule	Complete contralateral homonymous hemianopsia or incomplete incongruous contralateral homonymous hemianopsia
6. Optic radiation, anterior loop in temporal lobe	Incongruous contralateral homonymous or superior quadrantanopsia
7. Medial fibres of optic radiation	Contralateral incongruous inferior homonymous quadrantanopsia
8. Optic radiation in parietal lobe	Contralateral homonymous hemianopsia, sometimes slightly incongruous, with minimal sparing
9. Optic radiation in posterior parietal lobe and occipital lobe	Contralateral congruous, homonymous hemianopsia with macular sparing
10. Midportion of calcarine cortex	Contralateral congruous homonymous hemianopsia with wide macular sparing and sparing of contralateral temporal crescent
11. Tip of occipital lobe	Contralateral congruous homonymous hemianoptic scotomas
12. Anterior lip of calcarine fissure	Contralateral loss of temporal crescent with otherwise normal visual fields.

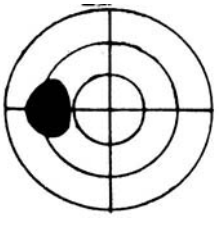


Fig. 8.3: Blind spot

Fig. 8.4A: Arcuate scotoma

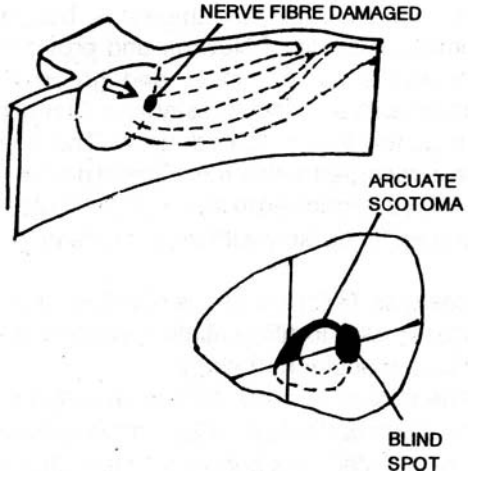


Fig. 8.4B: Glaucoma. This is a nerve bundle defect — here the fibres are compressed at their entrance to optic nerve head by raised intraocular tension

Central scotoma: It is associated with lesions of macula or papillomacular bundle of nerve fibres. Appreciation that the optic nerve receives it's blood supply from the ciliary circulation and not the central artery has clarified understanding of the field defects which occur in vascular disease.

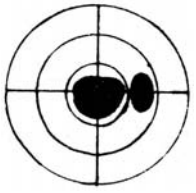


Fig. 8.5A: Central scotoma

Occlusive disease of the ciliary arteries may cause a segmental, quadrantic or hemianopic field defect in one eye and this may be lateral, oblique or altitudinal. The edge of the field defect passes through the blind spot and not the macula (Figs 8.5A and B).

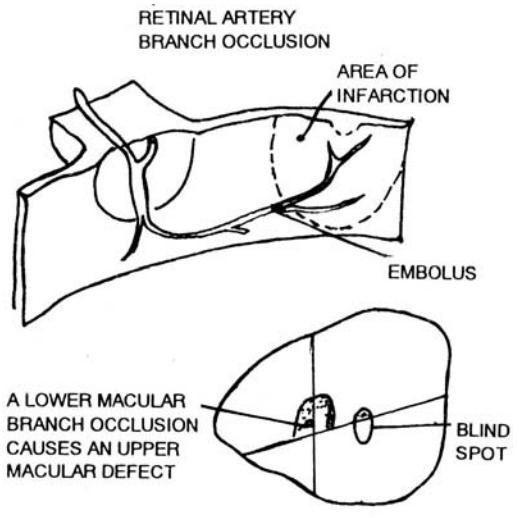


Fig. 8.5B: Retinal artery branch occlusion: The vessels are occluded by an embolus at a bifurcation

If both eyes are involved with vascular disease of the ciliary circulation, the field defect may be confused with a chiasmal or postchiasmal lesion.

Centrocaecal scotomas: Characteristic of tobacco amblyopia, this lesion is bilateral but may not be symmetrical and more coloured than white (Figs. 8.6 A and 8.6 B).

Junctional scotoma: This defect occurs in lesions involving the posterior pole of the optic nerve (optic nerve at junction of chiasma). Owing to the looping forward of the nasal fibres from the lower retina which cross in the chiasma they may also be involved. The effect of this is a central scotoma on the same side which may break through to the periphery and a defect of the upper temporal field of the other eye (Fig. 8.7).

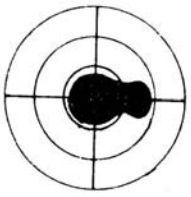


Fig. 8.6A: Centrocaecal scotoma

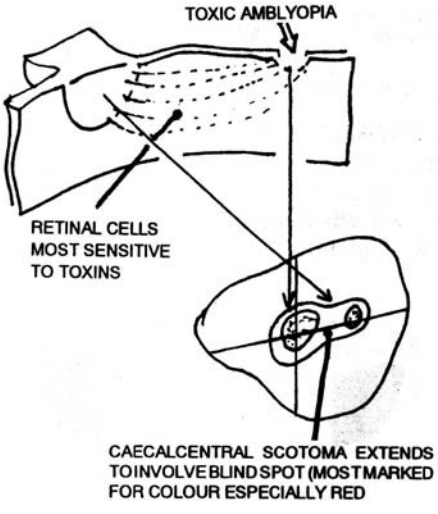


Fig. 8.6B: Toxic amblyopia caused by tobacco, alcohol, B_{12} deficiency, B_1 deficiency (drugs usually cause a central scotoma

Ring scotoma/concentric constriction of the field of vision/tubular field: In primary pigmentary degeneration, the field loss is slowly progressive and irreversible. Tubular field loss may occur as a transient event in migraine, as a hysterical manifestation and as a permanent effect of lesions of the occipital cortex which spare the posterior pole of the cortex and its connections (Fig. 8.8, Plate 17).

Bitemporal hemianopia: A lesion compressing the chiasma from below, e.g. pituitary tumour is likely to cause a field defect in the upper and outer (temporal) quadrant at first but the patient is unlikely to be aware of the field defect at that

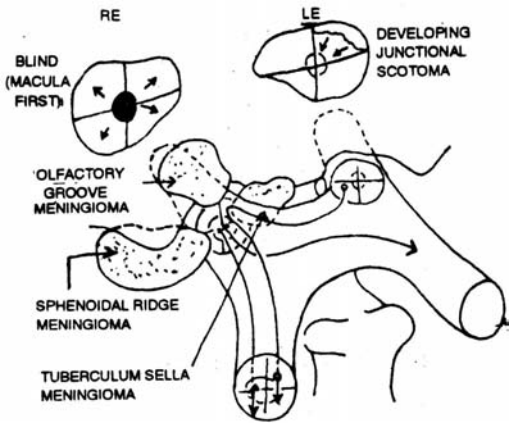


Fig. 8.7: Intracranial optic nerve compression

stage (Fig. 8.9C). Conversely, a tumour causing compression from above, e.g. suprasellar lesion, e.g. craniopharyngioma and suprasellar meningioma, will affect the lower temporal field first (Figs 8.9A and B).

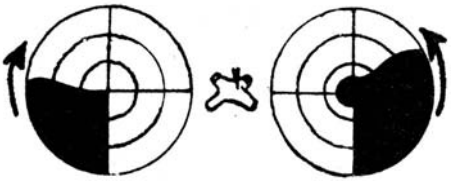


Fig. 8.9A: Bitemporal hemianopia

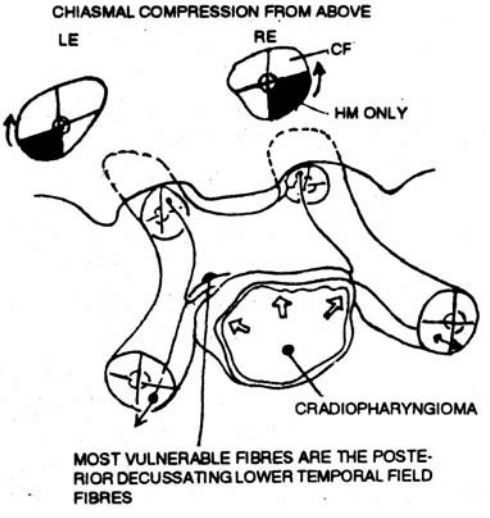


Fig. 8.9B: Chiasmal compression from above

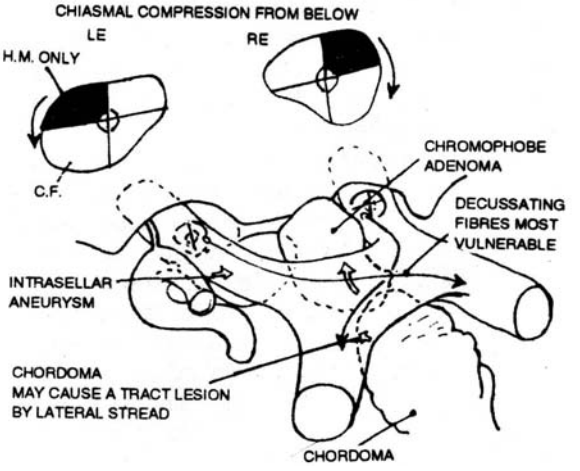


Fig. 8.9C: Chiasmal compression from below

Binasal hemianopia It is usually due to localised compression of the chiasma on its lateral aspect by thickened anterior cerebral arteries on both sides. A binasal defect is sometimes found in patients with optic atrophy secondary to raised intracranial pressure (Fig. 8.10).

Homonymous hemianopia: Some authorities believe that incongruous defect (the area of field loss for each eye being different) indicates at site of lesion and as the lesion is placed further back towards the occipital lobe the field becomes

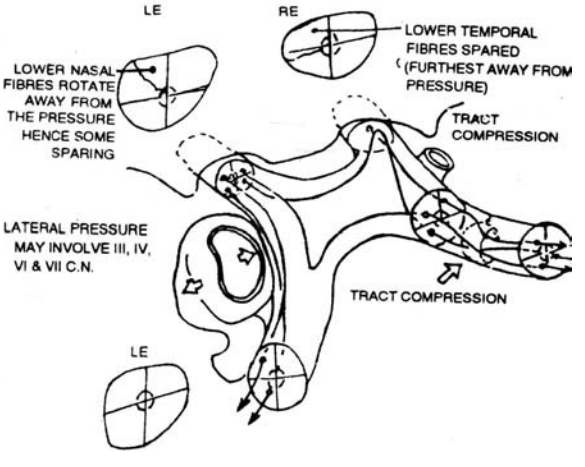


Fig. 8.10: Lateral chiasmal and optic tract compression

congruous. Incongruous defects may be due to a selective lesion of the lateral geniculate body. In the geniculate body the fibres are laminated in six distinct layers (Fig. 8.11).

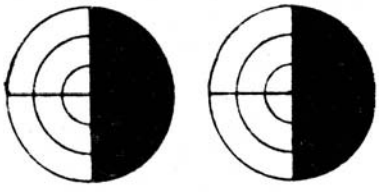


Fig. 8.11: Homonymous hemianopia

Homonymous quadrantinopia: An upper homonymous quadrantinopia is usually due to a lesion of the temporal lobe involving the visual fibres above or below the posterior horn of lateral ventricle (Fig. 8.12).

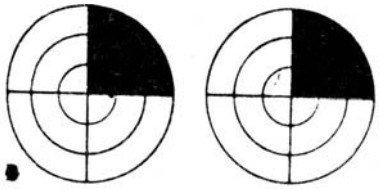


Fig. 8.12: Homonymous quadrantinopia

Altitudinal field loss: Monocular altitudinal field loss may be due to ocular disease and is a common feature of ischaemic optic neuropathy.

Bilateral symmetrical altitudinal loss may be due to a lesion of both optic nerves, the chiasma, or bilateral disease of the occipital cortex (Fig. 8.13).

Fig. 8.13: Altitudinal field loss

Crescentic scotoma: In the early stage of a compressive lesion of the optic radiation, the field defect may be confined to one eye and usually the eye on the side of the lesion. Central vision is usually spared and the defect begins at the periphery. It may be quadrantic or hemianopic and most often takes the form of a crescentic scotoma in the temporal field (Fig. 8.14).

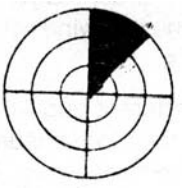


Fig. 8.14: Crescentic scotoma

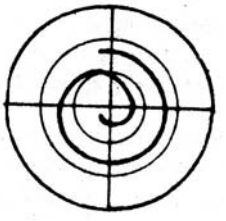


Fig. 8.15: Variable scotoma

Variable scotomas: An aneurysm which compresses the optic nerve or chiasma may be associated with striking day-to-day variations in field and acuity (Fig. 8.15).

Concentric constriction of the field may occur in compressive lesion. Variable concentric constriction may be due to psychological causes and the 'spiral' field which constricts progressively as it is charted, and then 'unwinds' as the procedure is followed in the reverse direction is suggestive of hysteria.

EXAMINATION OF THE PUPILS

Pupils must be examined for regularity of outline, size, reaction of light (direct and consensual) and reaction to convergence.

The size of the pupil can be measured with a ruler calibrated in millimetres. The pupils tend to be larger in children and diminished in size as one gets older. Normally myopes have larger pupil sizes. Any anisocoria (inequality of pupil size) must be carefully noted. Anisocoria may be due to local causes (iritis, etc.) or due to neurological causes (Fig. 8.16, Plate 18).

Light reaction test should be done preferably in a dimly light room and a strong pencil torch should preferably be used. The light should be focussed from the side while the patient looks ahead to avoid the added effect of convergence. In a normal individual, the pupil responds to direct light by constricting and there is also indirect or consensual response of the other pupil. The character of pupillary response is that at first there is an intial constriction which may be followed

by alternate dilatation and constriction (hippus). This is a normal variation. If the afferent arc of the pupillary light reflex is intact the direct reaction should equal the consensual. The following light reactions to the pupil are checked:

Marcus Gunn pupil If there is afferent pupillary defect (as in optic neuritis) the consensual response is greater than the direct response. If during the swinging flash light test, the amount of light information transmission is not equal in two eyes then following events may occur when the light is swung from the normal eye to the defective eye.

a. Immediate dilatation of the pupil instead of normal initial constriction (3-4+ Marcus Gunn pupil).
b. No change in the size intially followed by dilatation of the pupils (1-2 + Marcus Gunn pupil).
c. Initial constriction, but greater escape to a larger intermediate size than when the lights is swung back to the normal eye (trace Marcus Gunn pupil). It is seen in (a) optic neuropathy (unilateral or markedly asymmetric), (b) extensive retinal damage, (c) amaurotic pupil.

Positive and negative response in 3rd cranial nerve palsy (total) Pupil is dilated and non-reacting to both light and convergence.

Adie's tonic pupil A condition characterised by dilated pupil with poor or absent light reaction and slow constriction to prolonged near effort and still slow redilatation (tonic response) after near effort (Fig. 8.17).

The aetiology in most cases is unknown. The lesions causing Adie's pupil is located in the ciliary ganglion or short posterior ciliary nerves; aberrant regeneration of more numerous fibres innervating the ciliary muscle (97%) into those subserving iris sphincter muscle (3%).

Adie's syndrome Pupillary abnormalities occurring in a patient with associated diminished deep tendon reflexes (ankle jerk and knee jerk).

Argyl-Robertson pupil It is characterised by small irregular pupil which does not react to light but reacts briskly to convergence and doesn't dilate in darkness and shows poor response to mydriatics. The condition is usually bilateral (Fig. 8.18).

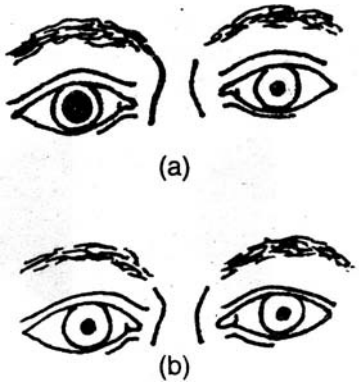


Fig. 8.17: Holmes-Adie's pupil. (a) No ptosis. Pupil is large, regular, does not react to light (other than prolonged exposure), may show some response to accommodation. (b) 2.5 per cent methachlone in both eyes, the sensitised H-A pupil promptly constricts, no effect on normal pupil (H-A pupils are usually unilateral)

Horner's syndrome (See Fig. 8.19) The pupil on the affected side is small but reacts to light and coverges normally.

Aetiology

(1) Neurosyphilis, and (2) other reported causes include diabetes mellitus, chronic alcoholism, multiple sclerosis, sarcoidosis, etc.

The site of lesion is most likely in the region of the sylvian aqueduct in the rostral midbrain interfering with the light reflex fibres and supranuclear inhibitory fibres as they approach the Edinger-Westphal nuclei. More ventrally located fibres for near response are spared.

In 80 per cent cases Adie's pupil demonstrates cholinergic supersensitivity to weak pilocarpine (.125% to 0.10%) and Mecholyl (2.5%) solutions.

Pupils of Coma

Hutchison's pupil Unilaterally dilated, poorly reactive pupil seen probably due to ipsilateral expanding, intracranial supratentorial mass (e.g.

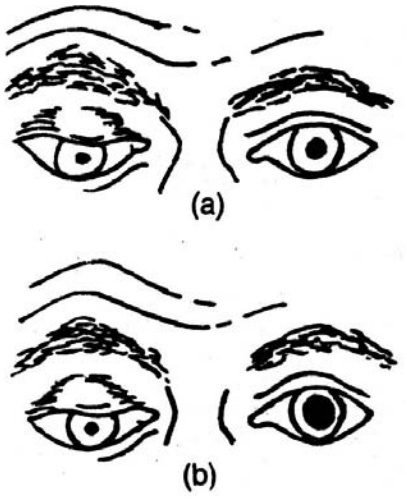


Fig. 8.18: Argyll-Robertson pupil: (a) Ptosis, Pupil is small, irregular, does not react to light, but does react to accommodation. (b) 1 per cent atropine drop in both eyes, no effect on A-R pupils, wide dilatation of the normal pupil (For illustrative purposes, left pupil is shown as normal. A-R pupils are usually bilateral though they can be asymmetrical)

Table 8.2: Spastic pupils

Miosis	*Mydriasis*
Meningitis	Epilepsy
Encephalitis	Schizophrenia
Syringomyelia	Aortic aneurysms
Horner's syndrome (Fig. 8.19)	Pulmonary carcinoma
Haemorrhage in 3rd ventricle	Mediastinal tumours
Drug Effects	
Miotics	*Mydriatics*
1. Parasympathomimetics: Carbachol, Pilocarpine, physostigmine	Sympathomimetics: Adrenaline, cocaine,
2. Sympatholytics: Guanethidine, Reserpine Phentolamine, Ergot	Parasympatholytics Atropine, Scopolamine
3. Others: Opiates, Histamines	Others: Bromides, Salicylates, Paraldehydes, Anti-histamine, Chlorpromazine, PAS

tumour, subdural haematoma) that is causing/ downward displacement of hippocampal gyrus and uncal herniation across the tentorial edge with entrapment of the oculomotor nerve.

Miosis During early stages of coma, the cortical inhibitory input to the Edinger-Westphal nucleus is diminished and the pupils are small but reactive to light.

Spatic pupil These are discussed in Table 8.2.

Swinging Flashlight Test

Technique With the room darkened, move the transilluminator quickly from one eye to the other across the bridge of the nose, closely watching the eye to which the light is moved. The light should be angled from below to avoid contamina-tion by the near response and should come from roughly the same part of each eye's visual field. Thelight should be swung briskly from one eye to the other, left on each eye for several seconds, and then swung back. Care must be taken not to expose one eye to significantly more light than the other.

Observation Immediate constriction ordilatation of either pupil upon direct stimulation is a positive result. Record the presence of an afferent defect as a positive swinging flashlight test, grading the defect on a scale of 4+ (dramatic pupillary escape of the worse eye or full scale direct constriction of the better eye)1to 1 + (just noticeable movement), specifying the abnormal eye. Record the absence of an afferent defect as a negative swinging flashlight test.

Interpretation This technique compares the patency of the visual pathways of the two eyes by comparing the eye's direct response (reflecting the sensitivity of its own visual pathway) with it's consensual response (reflecting the sensitivity of the other eye's visual pathway). When the light is swung quickly from one eye to the other, any significant movement in the pupil ofthe illuminated eye reflects a difference between it's consensual response (initial state) and it's direct response. Slight constriction upon illumination of each eye

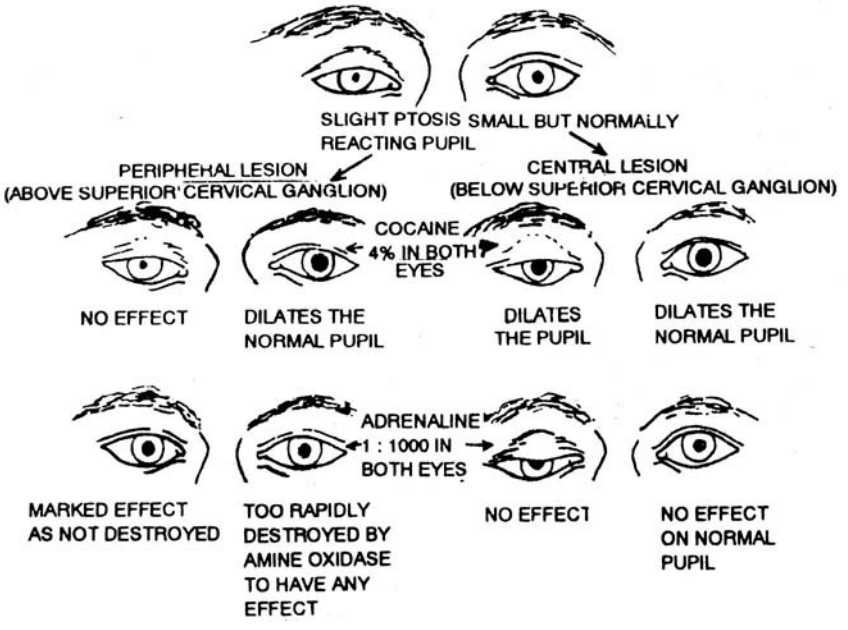


Fig. 8.19: Horner's syndrome

is caused by not moving quickly enough between the eyes. Slight dilatation that occurs shortly after the initial illumination of each eye is normal pupillary escape. Marked pupillary escape indicates pathology. Small oscillatory movements are due to normal pupillary "play".

FUNDUS EXAMINATION

Papillodema

It is the swelling of the disc due to accumulation of fluid. It is recognised by swelling forward of the disc in relation to the fundus. In papilloedema the disc assumes a bright pink colour and the swelling is usually first detected in the nasal side. The retinal veins are engorged and the venous pulsations are also lost. Sometimes the retinal arteries are submerged in oedema. Haemorrhage and exudates in the fundus may be associated (Fig. 8.20, Plate 18).

Pseudopapilloedemas may be due to hypermetropia, congenital abnormality of the disc or deposits of drusen. The congenital anomalies include persistent remnants of the hyaloid canal—Bergmeister papilla and coloboma.

Optic Atrophy

This denotes pallor of the disc which is outside the normal range. It may be generalised or local and is then often seen on the temporal side of the disc.

Based on the fundus appearance optic atrophy is commonly classified as primary, secondary and consecutive. 'Primary' optic atrophy is characterised by a clearly defined disc edge, with preservation of the physiological cup and normal retinal blood vessels and is due to disease of the optic nerve. Secondary optic atrophy shows an irregular disc outline with obliteration of the physiological cup and follows papilloedema. Consecutive optic atrophy occurs following disease of the retina or some other disorder of the eye, e.g. the excavated pit in glaucoma (Fig. 8.21, Plate 18).

The blood vessels should be seen for its origin, course, pulsation, calibre, abnormal A/V communication or neovascularisation. The

normal A/V ratio which is 2:3 may be altered in papilloedema because of abnormal venous dilatation. In hypertension and arteriosclerosis there will be gross narrowing of the arteries.

Macula is the most sensitive part of retina and lies temporal to the optic disc. In case of severe papilloedema the swelling of the optic disc may extend up to the macula.

The periphery of the fundus should be examined for haemorrhages, exudates, angiomatous malformation, parasitic cysts (cysticerus) or detachment.

Examination of retinal nerve fibres layer with green (red free) light is clinically important. Normal retinal nerve fibre layer is seen as a homogeneous, slightly opaque layer of regular striations arching from the disc. Defects may be diffuse, as after severe optic nerve damage, segmental, as following branch arterial occlusion or slit like, as in multiple sclerosis. It also helps distinguish between papilloedema (no striation) and pseudopapilloedema (normal striations).

The fundus examination includes the following details (1) optic disc, (2) vessels, (3) macula, (4) periphery.

Optic disc is 15 mm in diameter, slightly pink in colour and oval in shape. The margins are usually sharp except on the nasal side where it is often not well-defined. The temporal side of the optic disc is often paler than the nasal side. In papilloedema the disc assumes a bright pink colour and the swelling is usually first detected on the nasal side. The retinal veins are engorged and depending on the severity there will be presence of haemorrhages. (This condition must be differentiated from hypermetropia, drusen, medullated nerve fibres). In optic atrophy the colour of the disc is pale and the picture is variable in primary, secondary, and consecutive optic atrophies.

CLINICAL DIAGNOSIS OF CAROTID ARTERY DISEASE

Palpation of the pulse in the neck is unreliable as a sign of carotid artery obstruction but tortuosity of the vessels may be detected. A bruit which is localised to the area of the carotid artery is highly suggestive of stenosis but the narrowing may be in the external or the internal carotid artery. The haemodynamics of carotid circulation can be assessed by ophthalmodynamometry, thermography, oculopneumoplethysmography, recording of corneal pulsation, directional Doppler flow study or arm to retinal circulation time with fluorescein. A more direct method is by phonoangiography, audiofrequency analysis of the bruits, Doppler ultrasonic scanning, or realtime B-scan imaging.

OCULAR MOVEMENTS

This is described in detail in Chapter 7 on Strabismus.

Any defect of the 3rd, 4th and 6th cranial nerves if detected, the localisation of the site of lesion is very important.

Innervation of the Extraocular Muscles (Fig. 8.22).

3rd cranial nerve Superior rectus muscle, medial rectus muscle, inferior rectus muscle, inferior oblique muscles (and also levator palpebrae superioris in lid).

4th cranial nerve Superior oblique.

6th cranial nerve Lateral rectus muscle.

Anatomical Basis of Various Lesions (Fig. 8.23)

Oculomotor Nerve Paralysis

Localisation of the site of the lesion (Fig. 8.24, Plate 19) and its different manifestations (Table

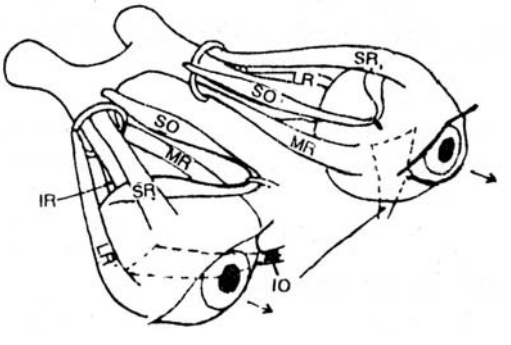


Fig. 8.22: The extraocular muscles

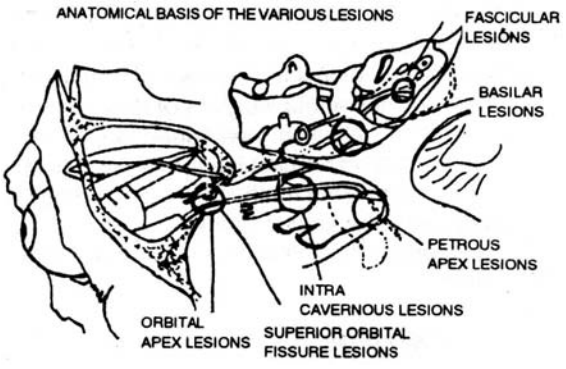


Fig. 8.23: Anatomical basis of the various lesions

Table 8.3: Different manifestations

Site of lesion			
Nothnagel's syndrome	*Benedict's syndrome*	*Weber's syndrome*	*Calqude's syndrome*
(Site superior cerebellar peduncle)	(Red nucleus)	(In the neighbourhood of cerebral peduncle)	
III. c.n. paralysis and cerebellar ataxia	III. c.n. paralysis and contralateral hemitremor	III. c.n. paralysis and contralateral hemiparesis	(Benedict's + Nothnagel's)

8.3) are described below:

Nuclear paresis A nuclear 3rd cranial nerve palsy on one side requires paresis of contralateral superior rectus with bilateral ptosis (levator palpebrae superioris paresis).

3rd cranial nerve fascicle syndrome (a) coexistence of other neurological sign, (b) ipsilateral, (c) virtually always ischaemic/infiltrative (tumour)/inflammatory.

Uncal herniation Supratentorial space occupying lesion may cause downward displacement and herniation of the uncus across the tentorial edge and cause compression of 3rd cranial nerve resulting in 3rd cranial nerve palsy along with Hutchinson's pupil (dilated and fixed).

Posterior communicating artery aneurysm at its junction with internal carotid artery: Isolated 3rd cranial nerve palsy along with pupil involvement.

Cavernous sinus syndrome Usually, associated with 4th, 5th, 6th cranial nerves and oculosympathetic paralysis, tends to be partial, i.e. all muscles are not equally involved, pupillary fibres frequently spared. and may lead to regeneration of 3rd cranial nerve.

Orbital syndrome Selective paralysis of structured innervated by only one of the divisions.

Pupil sparing isolated 3rd cranial nerve paresis It is spared in 80 per cent of ischaemic 3rd cranial nerve paresis and affected in 95 per cent compressive (trauma, tumour, aneurysm) lesions.

Abducent Nerve Paralysis

Localisation of the site of lesion [Fig. 8.25A (Plate 19) and Fig. 8.25B] is discussed below:

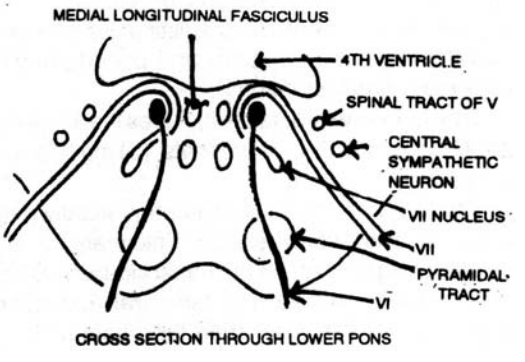


Fig. 8.25B: Cross-section through lower pons

Brain stem It may also have associated with 5th, 7th, 8th cranial nerve and cerebellar palsy.

The structure of lower pons may be affected:

i. Oculosympathetic central neuron lesion causes Horner's syndrome (ipsilateral).
ii. PPRF—ipsilateral horizontal conjugate gaze palsy.
iii. MLF—ipsilateral internuclear ophthalmoplegia.
iv. Pyramidal tract lesion causes contralateral hemiparesis.

The associated syndrome are the following:

a. Millard-Gubler's: 6th and 7th cranial nerve palsy alongwith pyramidal tract affection.
b. Raymond's: 6th cranial nerve palsy along with pyramidal tract affection.

c. Foveille's: 6th, 7th and 8th cranial nerve palsy along with PPRF affection and sympathetic involvement.

Subarachnoid space Associated increased intracranial pressure causes downward displacement of brain stem along with stretching of 6th cranial nerve tethered at its exit from pons and in Dorello's canal.

It is seen in pseudotumour cerebri, haemorrhage, meningeal/parameningeal infection (viral/bacterial/fungal), inflammation (sarcoidosis) infiltration (lymphoma, leukaemia, carcinoma), etc.

Petrous apex syndrome This is as follow:

i. *Gradenigo's syndrome:* It is a localised inflammation or extradural abscess of petrous apex following complicated otitis media.

It is characterised by paralysis of 6th cranial nerve along with decreased hearing (ipsilateral), facial pain (ipsilateral) along the distribution of 5th cranial nerve and facial nerve paralysis (ipsilateral).

ii. *Fracture of petrous bone (basal skull fracture following head injury):* It is characterised by the paralysis of the 5th, 6th, 7th and 8th cranial nerves, hemotympanum, Battle's sign and CSF otorrhoea.

iii. *Pseudo-Gradenigo's:*
   a. Nasopharyngeal carcinoma: It is characterised by serous otitis media and may invade cavernous sinus.
   b. Cerebello-pontine angle tumour: It is characterised by 5th and 6th cranial nerve paralysis, decreased hearing, ataxia and papillodema.

Cavernous sinus It is associated with involvement of 3rd, 4th, 5th cranial nerve, carotid oculosympathetic plexus (Horner's syndrome), optic nerve and chiasma and pituitary gland (Differential diagnosis—traumatic/vascular/neoplastic/inflammatory).

Orbital syndrome It is characterised by the following:

i. Proptosis, congestion of conjunctival vessels and chemosis.
ii. Optic nerve may be normal, atrophic or oedematous.
iii. The ophthalmic division of the 5th cranial nerve is involved (Differential diagnosis—mechanical restriction of the globe tumours, trauma, inflammations pseudotumour or cellulitis).

Isolated 6th cranial nerve palsy It is frequently postviral infection in young patient and ischaemic mononeuropathy in adults.

Trochlear Nerve Paralysis

Localisation of the site of the lesion (Fig. 8.26, Plate 19) is as follow:

Nuclear Fascicular syndrome (distinguishing nuclear from fascicular lesions is virtually impossible due to short course of the fascicles).

The aetiology may be haemorrhage, infarction, demyelination or trauma.

Subarachnoid space syndrome: The 4th cranial nerve is particularly susceptible to injury. If there is bilateral 4th cranial nerve palsy, the likely site is in the anterior medullary velum. The other causes include tumours (pinealoma, tentorial meningioma). meningitis and neurosurgical trauma.

Cavernous sinus syndrome: It is seen with 3rd, 5th, 6th cranial nerve and oculosympathetic paralysis. If the 3rd and 4th cranial nerves are involved together, testing for 4th cranial nerve is difficult and it can be done in abducted position and the amount of intortion is noted while the patient is asked to look down.

Orbital syndrome It is usually seen with 3rd, 5th and 6th cranial nerve paralysis and orbital signs, e.g. proptosis, chemosis and conjunctival injection.

The major causes include trauma, inflammation, infiltration and tumour.

Isolated 4th cranial nerve palsy (i) congenital—It is characterised by large vertical fusion amplitude (10 to 15Δ) and long-standing head tilt (by looking at old photographs. (ii) Acquired—It

is characterised by typical head position along with acute onset of vertical diplopia with tortional component.

Nystagmus

This term is applied to a disturbance of ocular movement characterised by involuntary, conjugate, often rhythmical oscillation of the eyes. These movements may be horizontal, vertical or rotary. In any given direction of gaze, the speed of the movement is usually quicker in one direction than the other. The quicker movement indicates the direction of nystagmus (Table 8.4). To examine the nystagmus, the patient is asked to look straight ahead and the eyes are observed. Then he is asked to look to his extreme right, then to the left and then upwards and downwards. It is best to ask the patient to look at the examiner's finger in these positions. The rate, amplitude and rhythm is observed in each direction.

Nystagmus is most commonly due to disorders of the vestibular system (either centrally or peripherally) (Table 8.4), to lesions affecting the central pathways concerned in ocular movements, e.g. vestibulocerebellar connections in brains stem or cerebellum or the medial longitudinal fasiculas, or to weakness of the ocular muscles. Nystagmus is often induced by drugs, especially benzodiazepines, phenytoin and other anticonvulsant drugs and barbiturates. Nystagmus of visual origin is pendular and often rotary on central fixation of the eyes. Congenital nystagmus also shows this pendular movement. Some forms of nystagmus (Table 8.5), particularly those associated with benign epidemic vertigo, and with posterior fossa neoplasms may be induced only by certain movements of the head (positional nystagmus); this nystagmus is of brief duration and can often be elicited only after a period of rest.

Optokinetic nystagmus occurs when the patient follows rapidly moving scenes.

X-RAY STUDIES

Following views must be taken while doing X-ray studies (Figs 8.27A to F):

i. Lateral view of the skull (Fig 8.27A) — for evidence of increased intracranial tension

Table 8.4: Directions of nystagmus

Items	*Peripheral (endorgan) nystagmus*	*Central (Nuclear) nystagmus*
1. Direction	Mainly unidirectional, fast phase opposite lesion	Bidirectional or unidirectional
2. Vertigo	Marked	Mild
3. Direction of environmental spin	Towards fast phase	Variable
4. Direction of pointing	Towards slow phase	Variable
5. Direction of Rombergfall	Towards slow phase	Variable
6. Effect of head turning	Changes Rombergfall	Nil
7. Vertical or purely rotary nystagmus	Nil	May be present
8. Durations of symptoms	Finite (minutes, days, weeks) but recurrent	May be chronic
9. Effect of vertigo and Nystagmus by visual fixation	Inhibited	Not inhibited
10. Common cause.	Infections, e.g. labyrinthitis, Meniere's disease, neuronitis, vascular trauma	Vascular demyelinating.

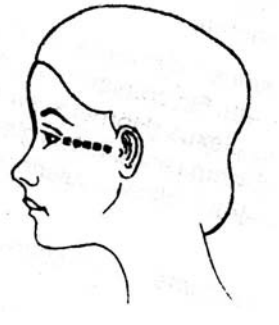


Fig. 8.27A: True lateral view: Note canthomental line the conventional radiographic baseline of the skull

Table 8.5: Types of nystagmus and site of lesion

Types of nystagmus	*Site of lesion*
1. Seesaw	Diencephalon and chiasma
2. Convergence retraction	Dorsal, rostral midbrain
3. Dissociated (abducting eye)	Medial longitudinal fasciculus also myaesthenia gravis
4. Periodic alternating	Caudal medulla
5. Gaze evoked slow in one direction, faster small amplitude in other	Extra-axial mass compressing stem side of slower nystagmus (as in acoustic neuroma, cerebellar hemisphere tumour)
6. Gaze evoked, spontaneous in one direction	Acute loss of vestibular function
7. Upward jerking in upgaze	Drug intoxication
8. Coarse upbeat, increasing on upgaze, decreasing on downgaze	Anterior vermis of cerebellum as in infiltrating tumours, fourth ventricular mass, nutritional cerebellar degeneration
9. Fine in primary, less in upgaze, more in downgaze	Medullary lesions (as in infarction)
10. Positional nystagmus.	Posterior fossa.

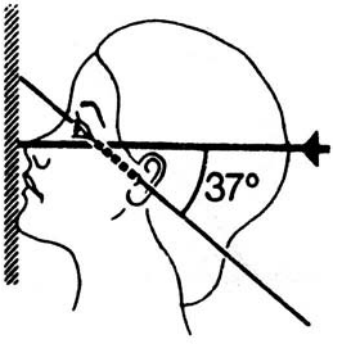


Fig. 8.27C: Waters projection: The tube is fixed at a right angle to the film, then the head is extended until the canthomental line lies at 37° to the central beam

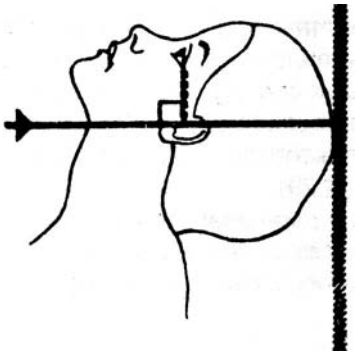


Fig. 8.27D: Submentovertex (basal, Hirtz's) projection, central ray at a right angle to the radiograph, but the head is thrown back to bring the baseline parallel to the radiograph

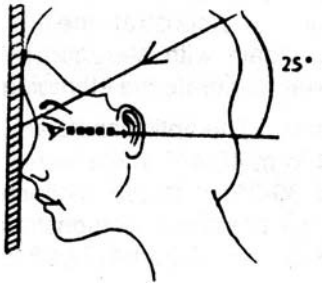


Fig. 8.27B: Caldwell projection: Posteroanterior central ray tilted 25° towards the feet

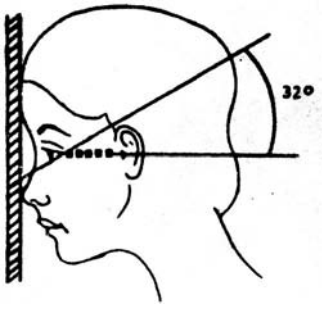


Fig. 8.27E: Optic canals (Ruggiero's method) The head is fixed relative to the film, and the tube is angled so that the central beam subtends the angles shown in the diagram

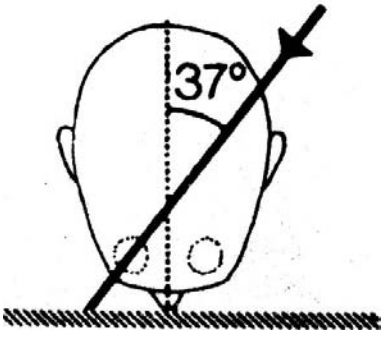


Fig. 8.27F: Correct oblique projection to demonstrate the optic canal

(beaten bronze appearance), sellar pathology (enlarged sella with destruction of posterior clinoid processes), increased vascular marking (Fig. 8.28, Plate 19).

ii. X-ray orbits—for evidence of enlargement, erosion of margins or fractures.

iii. X-ray optic foramen—for enlargement in glioma and meningioma of the optic nerve (Fig. 8.29).

iv. X-ray paranasal sinuses—for cases of mucocele of the frontal sinus, ethmoidocele, maxillary antrum growth, etc.

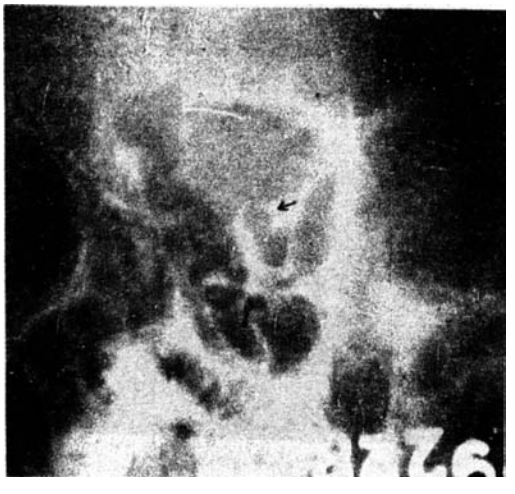


Fig. 8.29: X-ray showing enlarged optic foramen

v. Special X-rays—angiogram, pneumoencephalogram, etc.

PLAIN SKULL RADIOGRAPHY

1. A true lateral view to survey the skull vault and cranial cavity and to demonstrate the pituitary fossa.
2. A postero—anterior projection with 30° caudal tube to project the petrous bone below the lower margin of the orbit (Fig. 8.27B). This view allows a demonstration of the sphenoidal wings and superior orbital fissures together with the fall of the pituitary fossa. Carotid plexus calcification normally in the region of trigone may be unilateral and projected through the orbit on the PA 20° projection.
3. A half-axial projection with 30-37^{o} caudal tilt to demonstrate the petrous bone and the dorsum sella within the foramen magnum (Fig. 8.27C). Pineal body calcification is best viewed in this projection. Midline pineal body calcification occurs normally in 50-60 per cent of adult skulls and is within 3 mm of the midline.
4. Basal or submentovertical projection to demonstrate the skull base and the nasopharynx (Fig. 8.27D).

   Both pineal and choroidal calcification may occasionally be seen in children. Normal calcification may also be seen in the dura and petroclinoid ligaments.

Additional Plain Film Examinations

Paranasal sinuses The sphenoidal sinus is visible on the plain skull radiographs. Occipitomental projections sometimes with stereoscopy are necessary to demonstrate the antra. Oblique projections, again with stereoscopy, may be required to demonstrate the ethmoidal sinuses.

Optic foramen The optic canals are 5-7 mm in length and form 40-45^{o} angle with the sagittal plane, and 30-35^{o} with the orbitomental line. Correct oblique projections demonstrate the canal end on through the bony orbit (Figs 8.27E and F).

Plain Film Survey

Loss of normal translucency or change in shape of the paranasal sinuses should point to integrity of the adjacent orbital margins. Sinus infection is readily apparent but early neoplastic involvement, evident by bone destruction should be searched for. Expansion of a sinus cavity together with loss of normal scalloped outline is characteristic of a mucocele. The translucency of the affected sinus may not be affected. Mucoceles grow slowly and have a long symptom-free period. Soft tissue swelling in the nasopharynx may be a normal finding but in the presence of ophthalmoneurological features, attention must be directed towards the detection of destructive bone changes in the skull base which are of particular value.

Increase in size of the orbital cavity is usually due to long-standing intraorbital space occupation. The earliest changes are detectable as a depression of orbital floor. Decrease in size occurs as a result of bony encroachment from without or as a defect in growth, in absence of the globe. Apparent generalised loss of bone density within the orbit may be produced by increased bulk of soft tissue within the orbital cavity. True loss of bone density is due to a destructive bone lesion or its pressure erosion from a local space occupying lesion, e.g. mucocele. Most destructive bone lesions are metastatic either from local neoplasm or distant primary. Growth disturbance notably neurofibromatosis, may result in defects of the sphenoid. Increase in bone density affecting the sphenoid is most often produced by a sphenoidal wing meningioma. Fibrous dysplasia or osteoblastic metastasis may produce increased bone density. Bone sclerosis may be produced by spread of local infection giving rise to low grade osteomyelitis. Calcification may occur, rarely within the globe or in the lens. It is most frequently seen in retinoblastomas in children. An X-ray of the abdomen is essential to detect calcification in a possible primary tumour. Phleboliths are occasionally seen in varices or haemangiomas. Meningiomas may occasionally give rise to retrobulbar calcification. Sphenoidal fissure widening is most commonly seen in an aneurysm of the cavernous portion of the internal carotid artery.

Optic Canal

Minor variations in size between the two canals are common but a difference of over 2 mm is usually significant. An absolute measurement over 6.5 mm with standard focal film distance is generally considered abnormal. Anomalies in size and shape result from anomalous growth of the inferolateral wall of the canal formed by the inferior root of the lesser sphenoidal wing. Such developmental anomalies may give rise to apparent duplication of the canal. True enlargement of the optic canal may be due to expansion from within or erosion from without. Expansion from tumours within the canal results in symmetrical enlargement usually without erosion. The most common cause is an optic nerve glioma which is usually in patients under the age of ten and lying within the optic canal. Encroachment from outside the canal is more likely to cause bone erosion, e.g. cavernous sinus aneurysm. Neurofibromatosis may give rise to developmental changes in optic pathways including widening of the optic canal without tumour formation. Meningioma of the optic sheath may arise in adults within the optic canal. For abnormalities affecting the optic chiasma, particular attention should be directed to the pituitary fossa and the adjacent structures in both the lateral and axial planes, which should include observations related to erosion of the dorsum sella, changes in shape of sella, calcification in relation to the sella, bony changes in the adjacent skull base, and evidence of soft tissue enlargement in the nasopharynx. Enlargement of the pituitary fossa may be produced by tumours arising within the fossa or by raised intracranial pressure. The earliest change of raised intracranial pressure, occurring within 5 weeks of onset in adults, may be erosion on inner aspect of the base of dorsum sella (though vascular hypertension may produce a similar appearance). Later, pressure on the dorsum sella by an expanding 3rd ventricle may produce local bone absorption. Suprasellar masses, may first present radiologically in this way. Raised intracranial pressure in children may produce similar abnormalities of the pituitary fossa but

evidence of sutural diastasis is usually marked. Convolutional or digital markings in the skull vault are not of significance when found alone but in severe degree, when accompanied by other evidence in the form of sutural diastasis or sellar changes, may suggest long-standing raised intracranial pressure.

Ballooning of the pituitary fossa is usually due to intrasellar space-occupying lesion, commonly a chromophobe adenoma. The expansion may be symmetrical and responsible for the so-called 'double floor' to the pituitary fossa in the lateral projection. An unusually small pituitary fossa may be a feature of dystrophic myotonia where early cataract formation may be found.

The omega or J-sella characterised by a rounded enlargement of the infraclinoid compartment of the pituitary fossa and a well-defined cortical floor to the fossa is found in a variety of abnormal conditions, notably gliomas of the anterior optic pathway, gargoylism and chronic low-grade hydrocephalus. It may also appear in neurofibromatosis. Increased pressure upon the superior surface of the growing sphenoid, appears to be a common factor. Hyperostosis of neighbouring bone is most often produced by meningioma at its site of origin.

Pathological calcification above or adjacent to the pituitary fossa should not be confused with the normal linear calcification occurring in the petro and interclinoid ligaments. The most common cause of calcification above the sella is a craniopharyngioma, though it may also be seen in meningiomas and chordomas. Pituitary adenomas are occasionally calcified. Tuberculous meningitis, particularly after streptomycin therapy, may give rise to calcification deposits in the arachnoid. Parasellar curvilinear calcification in atheromatous carotid arteries is very common. Parasellar lesions may give rise to pituitary fossa enlargement by encroachment from the side but may, as in the case of parasellar meningioma or cavernous sinus aneurysm, give rise to erosive bone changes in the sphenoid, with possible expansion of the sphenoidal fissure.

Radiological investigation of lesions, affecting the radiations will therefore be directed towards the appropriate cerebral hemisphere and the supratentorial midline structures. A routine skull survey will be directed towards the demonstration of the following features:

1. Evidence of raised intracranial pressure manifested by (a) change in the pituitary fossa; (b) diastasis of sutures in children.
2. Displacement of the normally mid-line calcified pineal gland.
3. Changes in the skull vault due to bone erosion or new bone formation.
4. Pathological calcification is most common in atheroma of the carotid artery. Ten per cent of the intracranial gliomata calcify. Any glial tumour may calcify at any age but some pathological varieties (e.g. oligodendrogliomas) do so more frequently than others.

CT SCAN

It is a noninvasive technique that uses topographic X-ray films and a computer programme to record the relative tissue density of various areas, of the resultant cross-section. It helps in evaluating orbital mass lesions because of the great difference in density between the main orbital structures and the surrounding orbital fat. The retro-orbital or intracranial lesions can be well-demonstrated and various vascular lesions can be well-identified by it.

VEP STUDIES

It is the electrophysiological response generated by the occipital cortex which is time locked to a visual stimulation (light flash or pattern reversal). The VEP is a portion of the EEG (electroencephalogram) (Fig. 8.30).

VEP reflects electrical activity of the subject's central field, because central retina is projected on the surface of the occipital lobe and foveal projection is magnified at the cortex.

Under normal conditions the phobic stimulation of the retina gets transmitted to the occipital cortex, where it causes a change in the ongoing alpha rhythm of the brain. This change is very small in amplitude (5-20 microvolts), when compared to the background EEG activity and cannot be recorded by conventional EEG

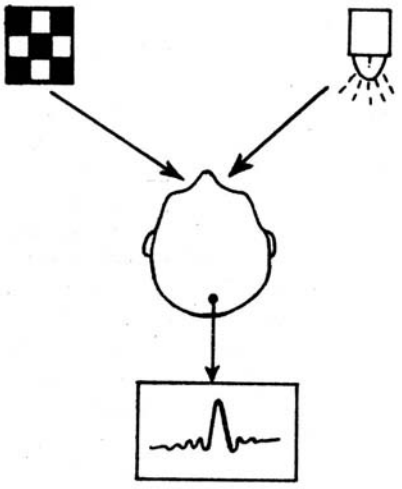


Fig. 8.30: VEP studies

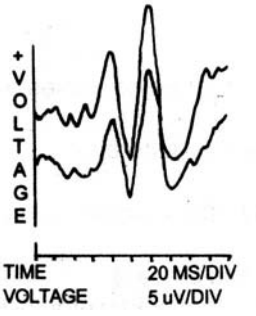


Fig. 8.31: Normal flash

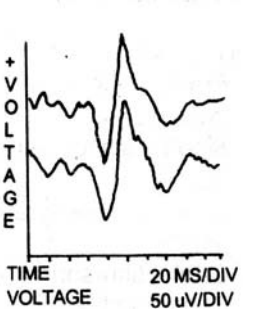


Fig. 8.32: Pattern reversal

machines. It is, therefore, necessary to signal average, to extract the VEP from ongoing EEG which can be done, by an averaging computer so if a series of identical time locked phobic stimuli are presented, computer averaging, can then substract the random EEG noise, recording only the visually induced electrical activity. There are two types of VEP—flash VEP and pattern VEP.

Flash VEP It produces a more complex M-shaped wave. There are two positive and two negative waves. The latency of 2nd positive wave (P_2) is considered (Fig. 8.31).

Pattern VEP It produces a simpler waveform which is less variable than flash VEP. The latency of the 1st positive wave (P_1) occurs at approximately 100 ms (Fig. 8.32).

Indication for VEP

Optic neuritis, multiple sclerosis, compressive lesions, cortical blindness, unexplained visual loss, macular function estimation and also for testing malingering.

Technique of VEP

The patient sits in a quiet darkroom and views the screen at a distance of 1.5 metres. One eye is tested at a time, the other being covered with a soft pad. The potential is recorded from an occipital electrode with a vertex reference electrode. The response is summated on-line in a computer and monitored in the recording room. A hundred responses are summated from each eye and the series is repeated. Latency is measured to the peak of the large positive potential. The normal latency is about 100 ms. If the patient is unable to see the pattern, a satisfactory recording is not obtained. In this situations, it may be possible to record the response to flash stimulation. Refractive errors increase latency and this can be corrected with spectacles. VEP may be lost or delayed, with disease of the eye or the visual pathway to the occipital lobe. It is most useful in identifying disease of the anterior visual pathway (pregeniculate).

In the common variety of optic neuritis associated with demyelinating disease, the VEP may be absent in the acute stage. In less severe cases it shows reduced amplitude and increased latency. The latency increase may be 80 per cent above the normal which commonly persists even when clinical recovery occurs. VEP latency is prolonged in patients with multiple sclerosis even without any visual disturbance.

The pattern VEP may be absent in optic nerve compression. With chiasmal lesions the waveform may be reduced in amplitude and distorted and the pattern from the two eyes becomes asymmetrical. A lesion of lateral geniculate body, optic radiation or occipital lobe is usually associated with homonymous, hemianopia and stimulation of the half field and comparison of the two

sides may reveal asymmetry of the VEP. Bilateral disease of the posterior visual pathway may cause an increase in latency. The response is usually absent in cortical blindness.

With amblyopia and disease like glaucoma latencies are delayed and amplitudes are reduced.

In interprating VEP, comparison between the two eyes is important. Amplitude is highly variable amongst individuals (25-30%) but latency is more or less constant (5-9%). When visual acuity has to be estimated the amplitudes of VEP are considered and when any lesion in the pathway is to be detected, the latency is considered.

CORNEAL SENSATION

A wisp of cotton is taken and touched at the sclera, near the limbus and gradually taken to the cornea. With normal corneal sensation, the patient will blink. Decrease in corneal sensation will be detected if both sides are compared. Local conditions like Hansen's, herpes should be ruled out. Similarly, cotton wisp may also be used to test light touch sensation of the brow and face, looking for differences from one side of midline to the other, with the patient's eyes closed.

Along with test, sense of smell, 5th nerve and 7th nerve functions are also to be tested.

TONOMETRY

Tonometry must be done routinely to exclude glaucoma in cases of Sturge-Weber syndrome, retinal vascular malformation, tumours of the intraocular portion of the optic nerve, in cases of central retinal vein occlusion, etc.

EXOPHTHALMOMETRY

Where proptosis is suspected, the distance between the outer orbital rim to the apex of the cornea is measured. A difference of more than 2.5 mm between the eyes should be suspected as proptosis. Every time same type of instrument should be used and must be recorded for subsequent follow-up.

OPHTHALMODYNAMOMETRY

This is done in suspected cases of carotid insufficiency. At first, the pupil is fully dilated then topical anaesthetics are instilled. Pressure is applied to the lateral aspect of the eyeball using a spring loaded plunger. With one hand, ophthalmoscopy should be done while with the other hand, plunger should be adjusted. The readings obtained are not the direct measurement of the pressure within the retinal circulation as there are other influencing factors also. A difference of 20 per cent between diastolic readings is considered as diagnostic of unilateral carotid stenosis or occlusion. This test is reasonably reliable when pressure in one ophthalmic artery is low. When ophthalmic arteries receive blood from collaterals (external carotid, meningeal or lacrimal vessels), this test will not reflect changes even if there is total occlusion of the internal carotid artery.

PULSATION OF THE CAROTID ARTERIES

Pulsation on both sides should be felt and heard for any bruit. Similarly, palpation of temporal and facial arteries should be done. Blood pressure should be checked in both arms at rest and on-standing.

SLIT LAMP EXAMINATION

Keyser-Fleishcer ring, corneal crystals, cataracts (dystrophia myotonica), pupillary abnormalities, etc. must be noted.

ADDITIONAL TESTS

- Prostigmine test—in suspected cases of myasthenia.
- Blood tests for—sugar, cholesterol.
- VEP.
- Fundus photography, fluorescein angiography.
- Orbital ultrasound (A and B scan).
- Previous photographs—to check for proptosis or changes in the facial contour (acromegaly) or strabismus.

Chapter 9

Examination of Retina and Vitreous

Usual symptoms of patients of vitreoretinal diseases are the following:

a. Dimness of vision
b. Metamorphopsia
c. Field loss or field cut
d. Flashes
e. Floaters

When a patient presents with any of these, proper history taking has to be done in the following way:

Personal History

Detailed history about diabetes mellitus, hypertension, blood dyscrasia, history of trauma or drug intake including duration, age of onset of disease and treatment undertaken should be carefully noted. Tuberculosis, sarcoidosis, connective tissue disorders and parasitic infestations may also be responsible for many retinopathies.

Ocular History

Injury to the eye, refractive status, previous history of any dimness of vision, flashes or floaters, history of any operation mainly intraocular are some of the points which may help in the diagnosis.

Family History

There are number of diseases like congenital and hereditary night blindness, macular dystrophies, etc. which run in the family.

Apart from these, retinal detachments and degenerations are found in members of the same family.

Maternal infections like toxoplasmosis, sexually transmitted diseases, etc. particularly during the first trimester of pregnancy may result in retinal pigmentary degenerations and macular changes.

History of prematurity in a child is important as retinopathy of prematurity (retrolental fibroplasia) is seen in many patients. This condition is rare nowadays, due to improvement in management of premature child.

The extreme retinal periphery or different vascular pathologies were not properly seen or understood earlier. With the availability of different diagnostic and investigative modalities, examination of the posterior segment of the eye has become much easier and accurate.

Special Diagnostic Methods

1. Fundus camera for fluorescein angiography.
2. Ultrasonogram.

This part of the chapter will deal with the instruments which are commonly used and their methods of usage. The following are the instruments which are required for thorough examination of the retina and vitreous:

1. Direct ophthalmoscope
2. Indirect ophthalmoscope — Monocular
   — Binocular
3. 3 Mirror lens
4. Hruby lens
5. 90D/78D lens
6. Pan fundoscope

DIRECT OPHTHALMOSCOPE

This is the most common and the most handy instrument for all around examination of the retina. But this has a lot of limitations.

i. The media has to be very clear otherwise it will obstruct the view. Mild to moderate degree of cataract, vitreous haemorrhage if present will make examination difficult or impossible.

ii. Direct ophthalmoscope magnifies images by 15 times or more, and hence only a small field of the retina can be visualised at a time, thus increasing the chances of missing out lesions.
iii. The extreme periphery of the retina is never visible. So lesions which are present between equator and ora serrata are better seen with an indirect ophthalmoscope.

Pupil Dilatation

For proper examination of the fundus, full dilatation of the pupil is very important. It is usually best achieved by the following:

a. combination of cyclopentolate (1%) and phenylephrine (10%).
b. combination of tropicamide and phenylephrine (5% or 10%).
c. combination of homatropine and phenylephrine.

It is not only important to dilate the pupil fully but good cycloplegia is also required because when the strong light falls on the eye, it becomes very difficult for the patient to keep the eyes open, or sometimes the pupil constricts under the strong light.

Apart from the white circular light which is usually used for viewing the fundus, there are other apertures meant to facilitate examination:

Streak Its function is limited. It is used to differentiate between cyst and hole or any elevation. Better way of doing is by Hruby lens or 3-mirror goniolens.

Red free light (green) Optic disc cup and pallor can be very easily ascertained by this light. Haemorrhages and pigments can also be differentiated.

Semicircular Any lesion near the macula can be seen in an undilated pupil by avoiding the light falling on the macula (or fovea in particular), thereby preventing pupillary constriction.

Graticules Its function as euthyoscope is not satisfactory. However, it can be used to estimate the size of a lesion (Fig. 9.1).

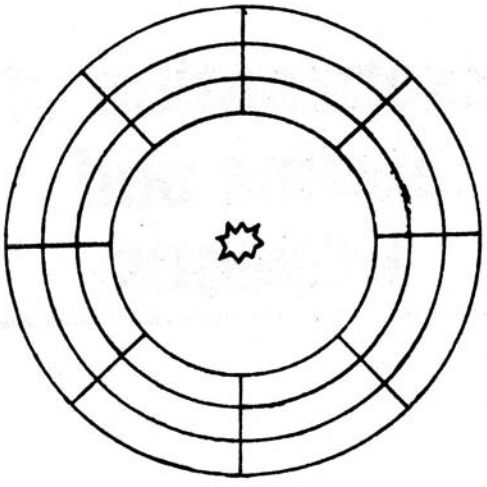


Fig. 9.1: Graticules

INDIRECT OPHTHALMOSCOPE

BINOCULAR

After the invention of this instrument vitreoretinal examination has become easy and perfect. The advantages over the direct ophthalmoscope are so many that gradually it is replacing the latter, and it is being preferred by many surgeons (Fig. 9.2, Plate 20).

Optics Figure 9.3 gives basic optics of indirect ophthalmoscope.

Parts of the Instrument

a. Viewing system
b. Illuminating system
c. Head band
d. Transformer.

Viewing system This system consists of two lenses which can be adjusted according to the interpupillary distance, thereby facilitating the maintenance of stereopsis (Fig. 9.4, Plate 20).

Viewing system has a rod which can be rotated to adjust the light which falls on plane mirror. Aperture selection is also present in the viewing system. Two other accessories are optional and are not present in all type of indirect ophthalmoscope, i.e. (1) filters, (2) teaching mirror. The

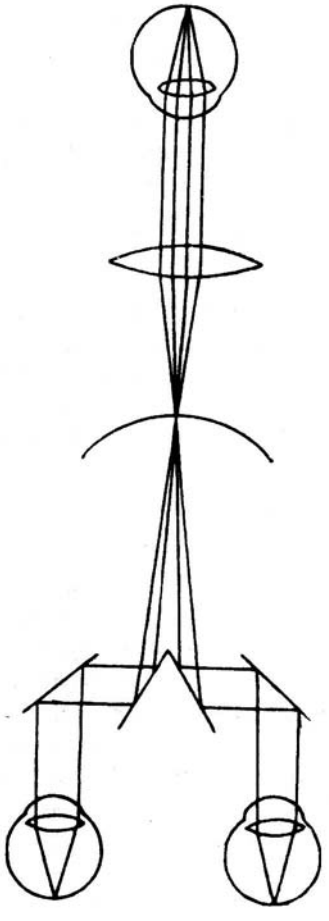


Fig. 9.3: Optics of indirect ophthalmoscope

filters may be detachable or fixed and help in fluorescein angioscopy.

Teaching mirror is a bimirror which is attached to the anterior position of the viewing system and helps for simultaneous viewing by colleagues. It reduces the illumination to some extent as it cuts off the light (Fig. 9.5, Plate 20).

Illuminating system This consists of a halogen bulb whose light falls on the plane mirror and is reflected to the eye of the patient.

Head band Is made of plastic and consists usually of two knobs. One on the back is used to tighten the band on the head (Fig. 9.6, Plate 20) and the other on the top, adjusts the height.

Transformer It is a step down transformer which reduces 220-230V to 5-15V. It also has a rheostat which controls the illumination according to need.

Condensing lens Three types of condensing lenses are available—14D, 20D, 30D. 14D lenses are not very comfortable to work with as it magnifies the object by about 5 times and the area of view is small.

Magnification of the object depends on the dioptric power of the condensing lens.

$$m = \frac{\text{Dioptric power of the eye}}{\text{Dioptric power of the lens}} = \frac{60D}{14D} = 4.3$$

20D lens is mostly used. 30D lenses on the other hand are used for small pupil ophthalmoscopy.

Fixation of the Head Band and Adjustment of PD
The head band has got 2 tightening screws. One on the horizontal and the other on the vertical band. These are tied according to individual need. Adjustment of PD—before putting on the light, see through the eyepiece whether they are centrally placed (Fig. 9.7, Plate 20). Now put on the light and allow it to fall either on a wall (Fig. 9.8, Plate 20) or on the palm (Fig. 9.9, Plate 21), at a distance of 2½ ft and check that it is visible equally through both eyes.

Holding the Lens
The condensing lens is held between the thumb and the index finger or middle finger, of either the right or the left hand, whichever hand one is comfortable. Ideally, one should be master in holding the lens by the both hands. The little finger of the same hand is used for fixing the lens by placing it on the forehead. Rest of the fingers of this hand and the fingers of the other hand is used to separate the lids (Fig. 9.10, Plate 21).

Method Full mydriasis is very important. The patient is made to lie down on a trolley, height of which should be around 27 inches depending upon the height of the surgeon. One has to be comfortable during examination otherwise he will become tired very shortly.

The trolley should be placed at a little distance from the wall so that the examiner can move all round the patient.

The patient lies down on his back looking straight up. Initially, difficulty is encountered when the light falls on the lens. There is too much of reflection and nothing is visible. The lens is tilted slightly and when the reflection goes, it is moved a little to and far from the eye till the fundus is visible.

Initially, for an inexperienced person, very little area of the lens is filled up with the image of the fundus. It is very important to fill whole of it. Gradually with experience, one will be able to do so by tilting the lens and moving it away from the eye at a particular distance.

Viewing of Retina

For viewing of retina the most important thing is to keep the light source, the condensing lens, and the patient's eye in one line or on one axis. By doing so optimum light enters the patient's eye and the whole condensing lens is filled up with a view of the retina.

For moving from one area to another two important points should be borne in mind:

a. While scanning different areas there should be movement of head and rest of the body in unison, so as to maintain a uniform axis of light source, condensing lens, and the patient's pupil at any given point; and there should be no movement of the neck since this would change the direction of the axis and hence the image formed will not be full and clear.
b. The body movement from one area to the other should be smooth and continuous, so that the lesions are not missed.

It is better to begin with the central retina first for the following reasons:

i. It is easy to obtain and recognise the image of the disc and macula.
ii. For making drawings of lesions it is also essential to begin with disc and macula because it not only helps in orientation but also in identifying vessels over the disc and their subsequent course.
iii. This also gives an idea of posterior extent of retinal detachment and involvement of macula.

Reflexes occur mainly due to the specular reflection of the air-cornea interface where maximum difference of optical density occurs. Following measures can be taken to achieve reflexless indirect ophthalmoscopy:

i. Slight angulation of condensing lens eliminates the reflexes to a great extent which separates the light reflected from the cornea and the illumination path.
ii. Maintenance of observer, condensing lens, and patient's pupil axis during retinal examination is important so that the image of light source and observer pupil's image is placed within the pupillary diameter of the patient.
iii. The image of the light source should be kept as far as possible from the images of the pupil in order to avoid reflexes. In practice, the image of the light source should be as far as possible from the image of the eye of the observer. To attain this state the rule of equilateral triangle should be followed; which means while observing the posterior pole the image of the light source and the two pupils of the observer should form a triangle inscribed in the patient's pupil and while examining periphery all three images should also be moved together so that it lied within the apparent ellipsoid pupil.
iv. To avoid reflexes a proper design of desirable lens is required. The proper design includes good quality glass, good quality coating and optimum dioptic power of lens with optimum diameter.

Scleral Indentation

The technique of scleral indentation has two main functions. The first is to make visible that part of fundus which is anterior to the equator and up to ora serrata and beyond. It is helpful when small holes or tears are covered by retinal folds or it could not be differentiated from retinal haemorrhage. A second and perhaps even more important

function is to enable the observer to palpate the retina and to examine critically the equatorial region.

The instrument which is best suited for use as a scleral depressor consists of a small, curved shaft with a flattened knob-like tip mounted on a thimble. The instrument can be grasped in several ways. It can be held between the thumb and the index finger, or it can be placed upon the index or middle finger. Each method of holding the depressor has certain advantages and can be used at different times to afford facility (Figs 9.11A and B).

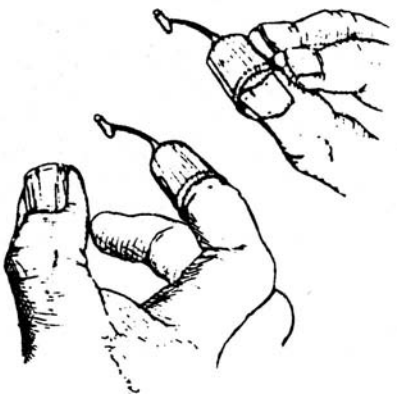


Fig. 9.11A: Methods of holding scleral depressor. The lower method is better as the third finger is free to hold the patient's lid

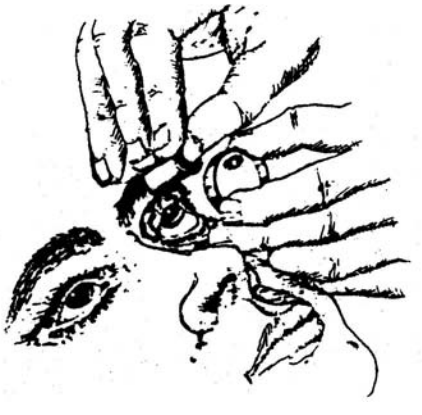


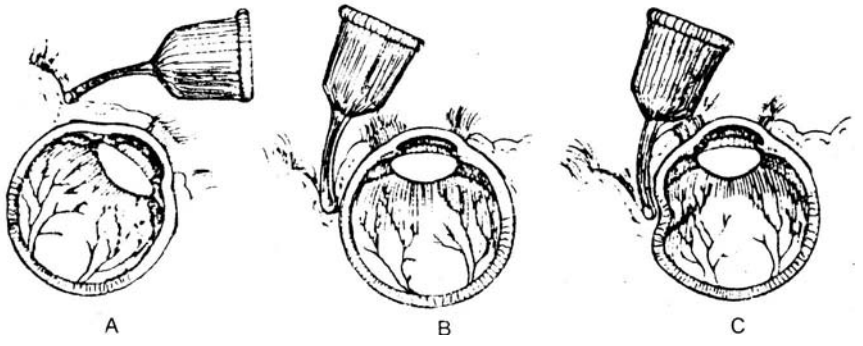
Fig. 9.11B: Fourth finger of examiner's right hand is used in steadying the depressor

The typical ora teeth and bays are only typical of nasal ora. Here, the characteristic distribution of pigment in the pars plana in this region can also be noted. The temporal ora serrata does not have noticeable ora teeth and bays, and the pigment band on the pars plana is somewhat thickened and pronounced. Cystoid degeneration is usually more prominent than on the nasal side. The demarcation between the retina and ciliary epithelium is less clearly marked temporally than it is nasally, and it is much easier to recognise the ora on the nasal side. Moreover, the absence of an overhanging orbital margin superonasally and nasally makes it easier for the scleral depressor to be applied here than on the temporal side.

To examine the superior part of the fundus, the scleral depressor should be grasped between the thumb and the index finger and the patient should be asked to look down. The depressor should be applied to the superior lid, without pressure, at the tarsal margin. The patient then should be asked to look up and as the upper lid retracts, the depressor should be slided posteriorly parallel to the surface of the globe (Figs 9.12 A to C). The depressor now lies against the globe held by the thumb and forefinger and no pressure is applied to the globe. The light from the ophthalmoscope is now projected onto the fundus superonasally, the condensing lens is interposed and the fundus at the equator is brought into view. The depressor should now be gentle pressed against the globe at the equatorial region and if it is applied in the correct meridian a grayish mound comes into view from the inferior part of the lens.

A small adjustment in the lens should now be made to clearly focus the image of the depressed and indented part of the fundus. The patient should be asked to look superonasally and the depressor should be slid anteriorly and slowly under direct visual control. The ora serrata should slide into view in the inferior part of the lens. The amount of pressure necessary to see the fundus with the depressor should not be so great that the patient is uncomfortable.

Once the image of the indented part of the fundus is visible, further parts are brought into



Figs 9.12A to C: Examination of superior parts of the fundus using a scleral depressor

view by direct visual control. The depressor, the lens, and the observer's head should move in a co-ordinated manner to move from one part of the retinal periphery to another. The observers eye, the eyepiece of the ophthalmoscope, the condensing lens, the patient's pupil, the part being studied in the fundus, and the scleral depressor all must lie on a straightline, the depressor should be applied in a direction as parallel to this axis as possible.

In most of the cases, scleral depression should be performed through the lids. Even the 9 O'clock and 3 O'clock meridians can be examined in most patient by careful application of the depressor on the upper lids. In some cases, it may be necessary to examine the 9 O'clock and 3 O'clock meridians by direct application of the scleral depressor to the bulbar conjunctiva. If this is done, it must be seen that even less pressure is applied to see the fundus. It is generally not necessary to use a local anaesthetic when applying the depressor on the bulbar conjunctiva. It is never necessary to use topical anesthetics when applying the depressor to the lids. If an occasional patient fails tolerate, the scleral depressor applied directly to the conjunctiva at 9 O'clock and 3 O'clock positions, a drop of a suitable topical anaesthetic may be needed.

In examining the ora serrata, it is usually necessary to tilt the condensing lens somewhat forward into a plane more nearly parallel to the iris. It is also sometimes necessary to tilt the light of the ophthalmoscope somewhat higher and tilt the mirror or eyepiece by adjusting the control screw of the mirror. One frequent error the beginners make, is to apply the depressor too far anteriorly; this causes considerable discomfort to the patient and will not permit visualisation of the retina.

By constantly moving the depressor with fine massaging movements anterior, posterior, and also sideways enable the observer to move lesions in the fundus and to examine them from many directions rapidly. This technique is sometimes referred to as rolling a lesion. This dynamic aspect of scleral depressor enables one to pick up lesions in the fundus that are invisible without scleral depressor.

The use of depressor allows us to detect and differentiate raised lesions from depressed ones in the fundus and to determine the difference between a haemorrhage and a retinal break.

Fundus Drawing

The problem of orientation in the fundus will be solved by learning to accurately draw the image that we see in the condensing lens. It must be remembered that the fundus image in the condensing lens is completely inverted, i.e. the image is upside down and also backwards as regards right and left. We, therefore, will consider the drawing chart upon which we will represent the patient's fundus and invert that on the patient's chest (Fig. 9.13). It will be seen that the 6 O'clock position on the chart faces up towards the patient's head. The 9 O'clock and 3 O'clock meridians on the fundus chart are also inversely related to 9

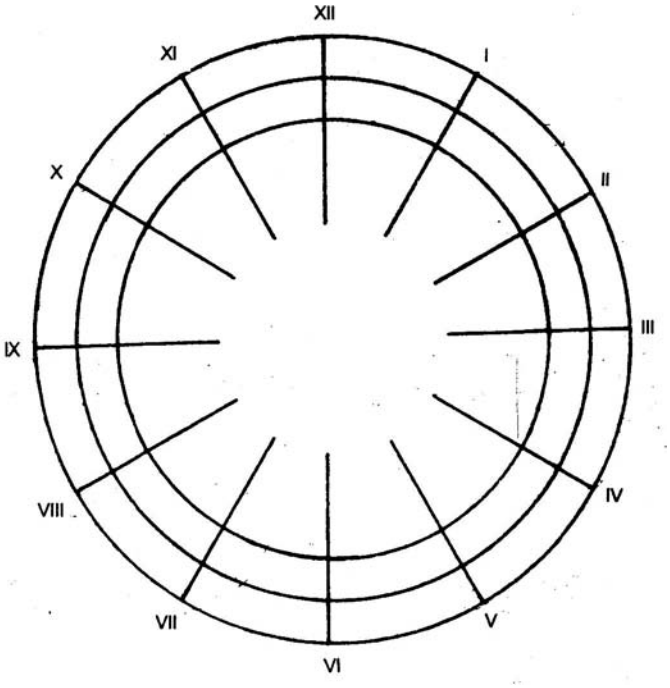


Fig. 9.13: A drawing chart for Indirect Ophthalmoscopy

O'clock and 3 O'clock in the patient's eye since the image in the lens is also inverted regarding the fundus, the image in the lens now corresponding exactly to the drawing chart. Therefore, if we merely transpose directly what we see in the lens to the drawing paper, all relationships will be correctly obtained. No attempt should be made to think in terms such as superior, inferior, temporal or nasal when performing this operation initially as these concepts become confusing while dealing with an inverted image.

One should attempt, when drawing a specific object in the fundus on the fundus chart, to stand 180° away from the lesion being observed. If we then look at the drawing chart, we will see that we are standing near the meridian we are observing. The important guide rule is that one should draw the image that we see in the lens as we observe it from 180° away, on that part of the fundus chart which is closest to us. One should begin by drawing an initial landmark, which could be a vessel or a specific spot; once the land mark is drawn it is easy to relate subsequent fundus land marks to the original one. After completion when the drawing is picked up and reinversed. It will be seen that a drawing has been made that is exactly the same, as if, it had been drawn by direct ophthalmoscope. By repeating the process over the over again it becomes easier to accurately reproduce what one sees in the condensing lens and gradually the problem of the inverted image seems less important.

Fundus drawing should be made on fundus charts which should be large enough so that adequate details can be reproduced. They should show all the meridians numbered by the clock. The equator and the ora serrata line should be present as well as a line indicating the extreme limit of view with depression on the ciliary body. The chart consists of three concentric circles. The inner circle represents equator, middle circle represents ora serrata, and the outer circle represents region of ciliary processes. The band between the middle and outer circles is the pars

plana of the ciliary body. The small circle in centre of the chart represents disc.

Coloured pencils are useful in giving a clear, concise reproduction of fundus pathology. It is convenient to use the correct colour according to the code. This method will result in drawing that have meaning to others familiar with the code and serve as a good record (Table 9.1).

The beginner should at least draw all veins in great details, paying attention to small changes in the vessel directions and to the accurate reproduction of branch relationship. Any distinctive pigmented areas or patterned areas, should be accurately reproduced. If a detachment of the retina is present, it is important to reproduce accurately the shape of a dominant retinal fold system, the position and shape of the retinal breaks and their relationship to the retinal vessels and other fixed hand marks.

In order to acertain that no area of the fundus escapes from the examination, a system of examination is essential. Otherwise, one is likely to miss lesions of considerable size and importance. One can start by drawing the fundus posterior to the equator, hour by hour on a dial. If one draws every retinal vein out to the equator, this method should assure coverage of this area. The area between the equator and the ora serrata is then examined separately by going around the eye, hour by hour with the scleral depressor, placing lesions on the chart in careful relationship to vessels previously drawn.

If a retinal detachment is present, it is usually best to chart out the dominant features of the detachment whatever they may be. Frequently, the balloons have a characteristic shape and can be plotted as a scaffold upon which to place the vessels and the retinal breaks. Particular attention must be given to the 9 O'clock and 3 O'clock meridians, since lesions at or anterior to the equator in these meridians are easy to overlook due to technical difficulty of applying the scleral depressor here.

Method of Examination

Preparation of the patient The first prerequisite for an adequate examination is that the patient

Table 9.1: Standard colour codes for fundus drawing

Colour codes	*Structures/lesions*
1. Yellow solid or black cross	Hard exudate
2. Yellow outline or black circle	Soft exudate
3. Red	• Retinal haemorrhage • Cystoid macular oedema • Attached retina • Disc • Arteries
4. Red and green centre or only green	Vitreous haemorrhage fresh or organised
5. Silver or Gray	Silver wiring
6. Yellow over red/ blue line	Sheathing
7. Orange	Neovascularisation flat
8. Purple	Projecting into the vitreous
9. Black outline with brown outline insides	Preretinal membrane starfolds Zonular traction tuft Meridianal folds Paving stone
10. Blue outline	Detached retina
11. Blue forward dentate process	Ora
12. Blue	Veins Detached retina Traction tuft
13. Red attached blue detached	Macula
14. Blue shade over solid red	Retinal oedema
15. Green	Media opacities
16. Blue outline with red cross	Thin retina
17. Blue outline with blue cross	Lattice
18. Blue outline, red shade	Hole
19. Blue circles at ora	Peripheral cystoid degeneration
20. Blue outline with blue cross hatch	Schiasis
21. Blue shade with blue outline Blue outline cross hatch	Cysts
22. Black	Retinal pigmentation choroidal pigmentation when seen through the attached retina
23. Brown	Detached retina. Choroidal pigmentation seen through detached retina.

should have at least some idea of what he should expect during the examination. He should be warned that the light is intense though harmless to the eye.

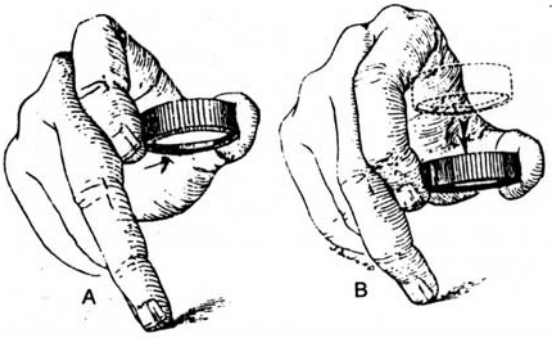
The pupil should be adequately dilated. The most satisfactory dilatation is achieved by the use of any cycloplegic plus 10 per cent Neosynephrine drops. The combination produces a wide and lasting result. The choice of a cycloplegic is determined by how long the examiner wants the pupil to remain dilated and not by how widely he wants it to dilate. Maximum dilatation may be impossible in some eyes due to posterior synechiae, secondary membranes, sphincter damage or other causes. Such patients are difficult to examine. The positioning and the fine movements of the condensing lens become much difficult. An experienced examiner can see through a miotic pupil but with difficulty.

Nothing should be instilled which might cause corneal haziness. Topical anaesthetics such as tetracaine or cocaine often result in epithelial oedema and may make the appreciation of fine details difficult. Ointments of any kind should not be used as they make the lids slippery and cause blurring of the image.

The patient should be positioned lying flat on a stretcher. The supine position is of great advantage over the seated one. The stretcher should be just high enough to reach the examiner's hips. The patient's head should be unsupported. If any dorsal kyphosis is present, a small flat pillow should be used to prevent hyperextension of the neck and to assure comfort. The neck should not be flexed at this stage of examination, and the table/stretcher should not be tilted up, since this makes examination of some parts of the periphery of the retina, difficult.

The examination proper The patient should now be asked to look in the cardinal positions of gaze. This helps the examiner to find out how well the patient can follow such commands. Some patients have poor voluntary control of eye movements. In such cases, it is advisable to have the patient hold out his own hand as a fixation object and look at it. The patient must be repeatedly urged to open the fellow eye. The examiner holds apart the lids of the eye being examined. If the patient closes the other eye, Bell's reflex will cause the examined eye to roll up also. It is useless to have the patient hold the fellow eye open with his hand, since this only intensifies the Bell's reflex. Constant reminding may be necessary to keep the patient from allowing the opposite eye to close. As he becomes more light adapted, this tendency decreases.

Holding the condensing lens The problems now arises as to with which hand to hold the condensing lens. The first impulse is to hold it in the hand with which one ordinarily, writes. This may make the initial viewing of the fundus easier but will result in difficulties later on when deciding with which hand to hold the scleral depressor. It is better to use the writing hand for the scleral depressor and the other hand for holding the lens. This may prove initially difficult but in the long run affords greater facility for examination. One should consistently use the same hand to hold the lens; otherwise it will be difficult to develop the reflex skills. The precise manner of holding the condensing lens is of critical importance. It should be grasped between the tip of the flexed index finger and the ball of the extended thumb. The wrist should be flexed moderate and the third, fourth, and fifth fingers should be extended. The extended third finger is used to hold the upper or lower lid of the patient-which lid depends on the side of the patient one is standing on. The thumb of the opposite hand is used to retract the lid not held by the third finger (Figs 9.14A to C). With the fourth and fifth fingers of the hand which is holding the lens, and with the other hand, the examiner holds the patient's head firmly. The extended third finger acts as a pivot which enables the observer to tilt the lens in all planes merely by rocking the forearm on the tip of the finger. The lens can be moved with critical control closer or further away from the eye (Fig. 9.14D) by increasing or decreasing the flexion of the index finger. If the lens is incorrectly grasped between the ball of the index finger or the terminal joint of that finger and the ball of the thumb, it is difficult to make the fine



Figs 9.14A and B

adjustments in lens position so essential to critical scanning of the fundus.

Any dirt or fingerprints on the lens surfaces cause great interference with the view of the fundus. Such dirt causes more difficulty in seeing the retina. The condensing lens must be kept scrupulously clean and free of fingerprints.

Some Important Points during Indirect Ophthalmoscopy

a. Always keep the flat surface of the lens towards the patient. Double aspheric lenses can be used on both sides.

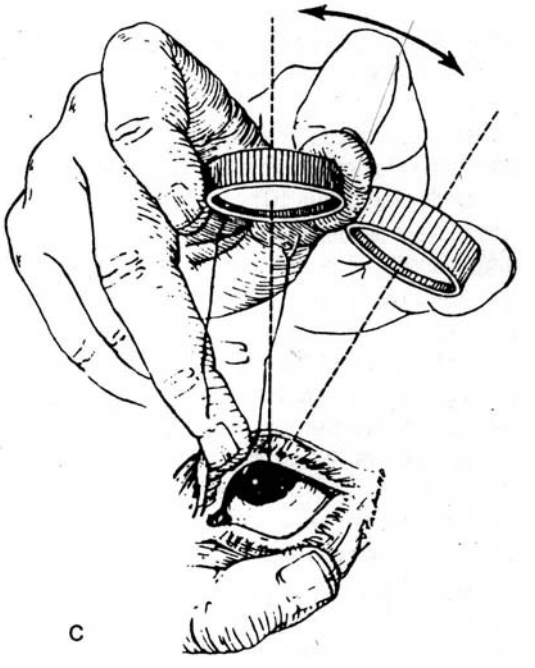
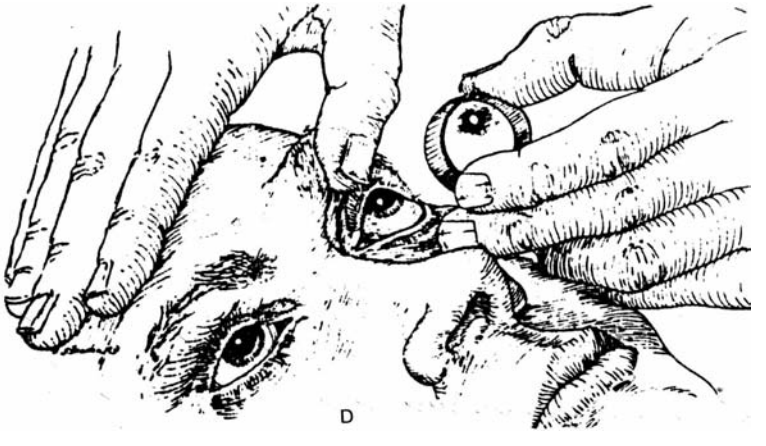


Fig. 9.14C

b. Sometimes during examination the object of interest may go out of the field. So always search for it in the opposite direction to which you think it has gone.
c. In some cases the pupil cannot be dilated fully inspite of all measures. In these cases, reduce



Figs 9.14A to D: Methods of holding the lens: (A) The lens is grasped between ball of thumb and tip of index finger. Wrist is extended and third finger is extended as pivot. (B) Manner in which the lens is moved closer to or away from the eye. (C) Extended third finger holds the upper lid open and thumb of the opposite hand holds lower lid. (D) Examination of superonasal part of fundus. Examiner stands to the left of the patient and third finger of the left hand controls lower lid. The right hand controls head and the thumb of the right hand controls the upper lid

the PD of the ophthalmoscope and try to see with a + 30D lens. The small pupil indirect ophthalmoscope may be of some help.

Fluorescein Angioscopy

Blue filter of an indirect ophthalmoscope can be used for fluorescein angioscopy, where the facilities for fluorescein angiography is not available. The former is very useful for diagnosing macular lesions and it can be done in the OPD without any extra-expenditure.

All that is required is a fully dilated pupil, fluorescein dye ampoule (3 ml 20%) and a nurse or an assistant. Emergency medical kit like oxygen cylinder, injection of decadron, adrenaline, etc. are also required.

After proper consent from the patient about its usefulness and its side effects, he is made to lie down on the trolly where indirect ophthalmoscopy is done. The part of the fundus to be examined is focussed and when the eyes of the patient are made steady, the blue filter is fitted. In the meantime, the assistant should be ready with the fluorescein injection in a disposable syringe with a 22 gm needle. Since the dye is injected in the antecubital vein, the arm is fully extended, the area cleaned and the needle is pushed inside the vein.

The blue filter areas of pseudofluorescein are seen and the dye is injected in a shot. After few seconds (8-10 sec) choroidal flush appears followed by arteriolar filling, venous filling, etc. CSR, disiform degeneration, any other leaking areas and subretinal neovascularisation can be seen clearly, but the main disadvantage is that they cannot be documented.

MONOCULAR

Method The patient can be examined in both sitting and lying down positions. The examiner holds the indirect ophthalmoscope in his one hand while the other hand holds the condensing lens. The distance between the patient's and examiner's eyes should be at arm's length. Since it is monocular only one eye has to be used for examination.

The condensing lens is brought near the patient's eye and the indirect light is focussed on the lens. By forward and backward movements and tilting of the lens, the retina will be visible. Extreme periphery of the retina can be seen only when the patient is examined in lying down posture. Rest of the examination part is similar to that of binocular indirect ophthalmoscope.

SLIT LAMP EXAMINATION OF FUNDUS

The slit lamp biomicroscope is a stereoscopic microscope which cannot focus directly on the retina because of the optical system of the patient's eye. It can focus only 4 inches in front of the objective lens. (Haag Strait 900 slit lamp is considered). If one considers the eye as a projector, the retina is imaged at infinity by the optical system of the eye. Since the slit lamp can focus only up to 4 inches, an external optical aid is required to bring the retina in view.

This external optical may be a contact lens (Goldman 3 mirror lens) or a noncontact lens (Hruby lens, 78D, 90D lens).

GOLDMANN 3-MIRROR LENS

The 45D corneal surface refraction is replaced by a flat afocal lens. This instrument has got immense usefulness as it can be used to see the disc, central retina, posterior pole upto the equator and beyond (Figs 9.15A to D).

Parts

1. Central lens through which the disc and posterior pole is visible.
2. Gonioscopy mirror (smallest tongue shaped) for viewing the angle of the anterior chamber.
3. Middle sized bigger mirror for examination of the fundus beyond the central retina and up to the mid periphery.
4. The largest size mirror for fundal examination between extreme and mid periphery.

Method

For retinal examination the pupil should be fully dilated. Four per cent lignocaine is instilled in both eyes. After the topical anaesthesia is complete

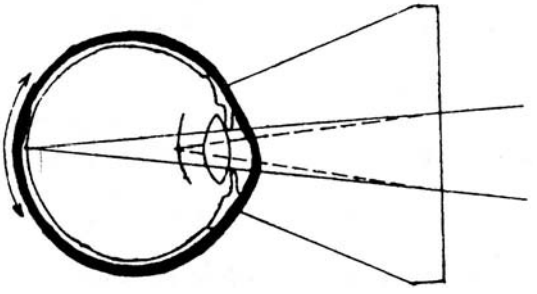


Fig. 9.15A: Goldmann 3-mirror lens

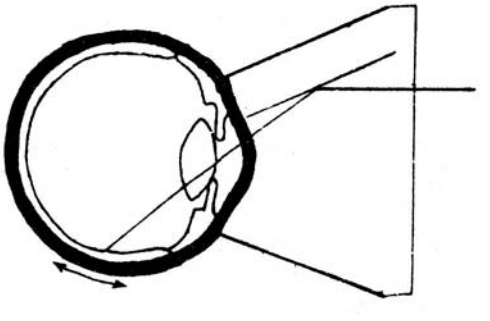


Fig.9.15B: Optics of posterior retinal mirror. Arrow shows range of view that can be obtained by moving eye or lens

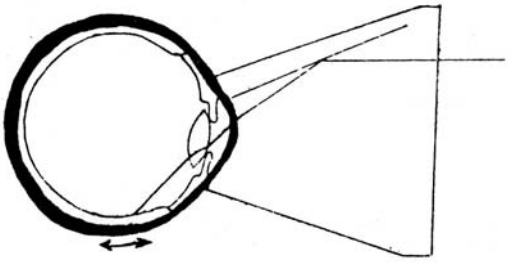


Fig. 9.15C: Optics of anterior retinal mirror. Arrow shows range of view

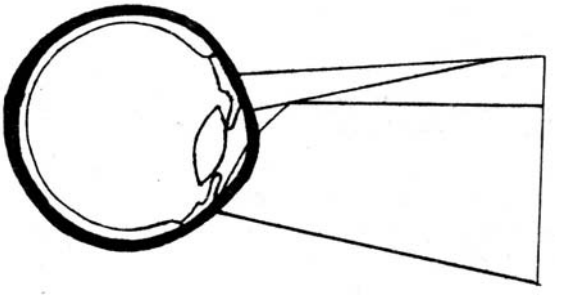


Fig. 9.15D: Optics of gonioscopy mirror

the patient is made to sit in front of the slit lamp, keeping the chin in position. The concave portion of the 3-mirror contact lens is filled with 2 per cent methyl cellulose (or 0.75% commercially available methyl cellulose eye drop). The mirror is held in one hand and with the other hand the eyelids are separated by using the thumb and the middle finger or index finger, fixing it at the superior and inferior orbital rim. If the right eye is to be examined the mirror is held in left hand and vice versa. It becomes much easier to insert the lens in this way. In case of right eye examination, the eyelids (both upper and lower) are separated by the thumb and the index or middle finger of the right hand. The patient is asked to look up and the contact lens is put in the lower fornix. Now ask the patient to look down and the upper part of the contact lens is inserted, keeping the lids separated. After insertion, the mirror is rotated 2-3 times clockwise, so as to remove any air bubble and also for proper contact with eye [Fig. 9.16 and Fig. 9.17 (Plate 21)].

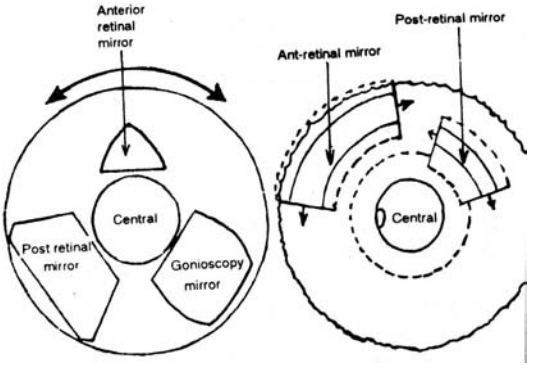


Fig. 9.16: (A) Three mirror lens as seen by viewer, (B) solid lens represent zones of retina visible by retinal mirrors and central lens. Dotted lines represent additional area visible all 360°.

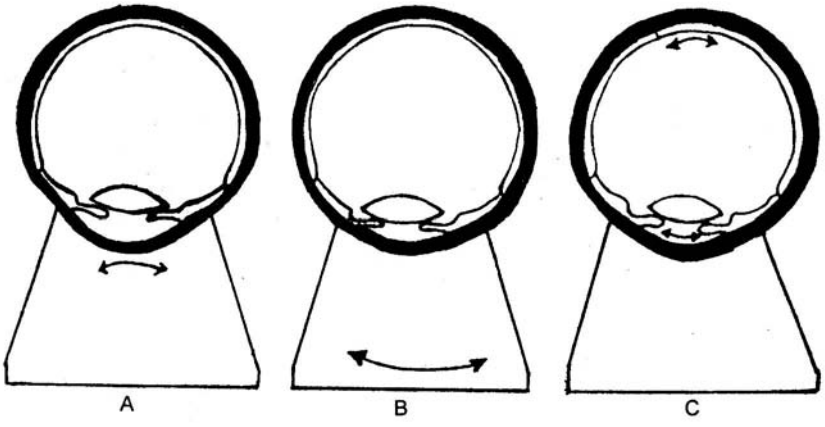


Fig. 9.18: Maximum retinal area visible by: (A) moving apex of lens to view different parts of retina., (B) tilting base of the lens., (C) rotating patient's eye.

The slit lamp beam is kept straight so that it is equally visible through both the eyepieces.

The beam is then passed through the central lens and then focussed on the disc and macula. The lens is slightly tilted to the right or to the left, along which the eyeball also moves and the desired area is brought into view.

To distinguish between a macular hole or a cyst, the beam is made very thin and as it falls on the lesion it can be easily differentiated (Fig. 9.18).

Fluorescein angioscopy can also be done by this technique using the blue filter of the slit lamp. Macular degeneration, posterior staphyloma, neovascularisation, optic disc cup, coloboma, pits, etc. are very well-appreciated by this lens.

Besides gonioscopy, two other mirrors are used to view the fundus. The image formed on the mirrors are actually on the opposite side of the fundus. The 3-mirror is rotated by 360^{o} so as to assess the full retina. Peripheral retinal lesions like lattice degenerations, tears, holes, etc. are visible. Hence it is a very important diagnostic kit and can be used for certain cases where even after indirect ophthalmoscopy the lesions are not properly visible. Media should be absolutely clear to get a good view.

In apprehensive and slightly unco-operative patients with small palpebral aperture another way of inserting the mirror is the following:

1. Hold the lower lid by the thumb.
2. Keep the middle or ring finger on the upper lid margin and drag the upper lid up, towards the upper bony rim and fixing it tightly so that even with squeezing it does not move.
3. The concave part of the 3-mirror is filled with methyl cellulose and in an angled direction (up and towards the patients) is brought close to the patient's eye.
4. The lower part of the lens is inserted into the lower fornix and the upper part of the mirror is placed very quickly on the cornea (Fig. 9.19, Plate 21).
5. Position the lens properly and rotate 2-3 times.
6. Release both the lids.

Examination of the peripheral fundus is done with the help of 2 mirrors (third mirror is gonioscopic mirror). When the mirrors are at 6 O'clock and 12 O'clock position, the slit is made to fall vertically on it. Similarly, when the mirror is at 3 O'clock or 9 O'clock position the slit is made horizontal. In other words, the slit beam is made to fall perpendicular to the mirror and parallel to the meridian of the fundus to be examined. The mirror is rotated 360^{o}, tilted side to side and up and down so that whole of the fundus is visible. It should be kept in mind that being a mirror it gives the image of the opposite side of the retina.

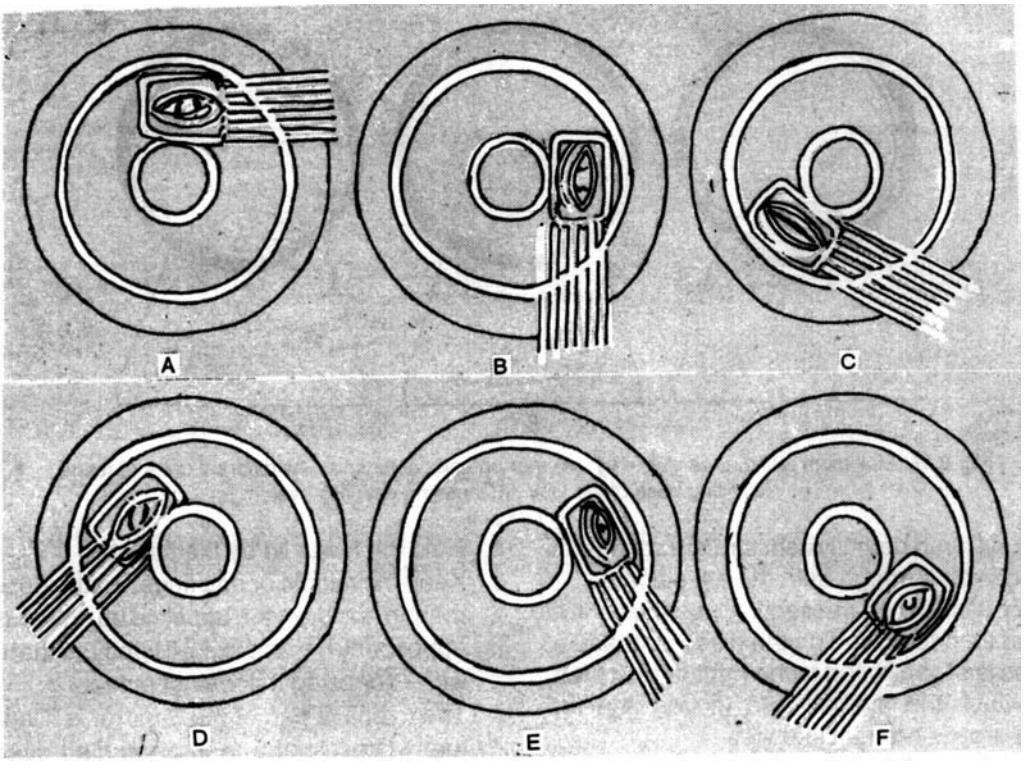


Fig. 9.20: Slit lamp examination of peripheral retina. Light is allowed to fall on the mirror perpendicularly so that the diagonally opposite area to the mirror is visible

Start examining the fundus from a particular point through one mirror. After completing 360° examination, select the next mirror and proceed likewise. After thorough examination, see any particular part of the retina which needs special attention. Tilt the lens from the base or the apex so that all the angles are visible (Fig. 9.20).

Scleral depression It is done to see the peripheral retina properly as in indirect ophthalmoscopy.

Special attachments for the Goldmann three-mirror are available but it can be conveniently done with a wilder type of depressor. Method of depression is similar to as described before.

Removal of 3-mirror lens Ask the patient to look down and press with upper sclera just above the lens with a finger and pull the lens gently. It will come out easily.

HRUBY LENS

The principle of this lens is same except that contrary to Goldmann lens, which is a contact lens, this lens is kept away from the eye and only the posterior pole is visible.

The power of the lens is 60D which neutralises the refractive power of the eye.

A virtual image is formed at a distance of about 18 mm from the patient's retina when the lens is kept 10-12 mm from the patient's eye (Fig. 9.21).

The disadvantage with the Hruby lens is that the angle of view of the retina is very small.

Method The patient is seated in front of the slit lamp and the chin kept in place.

The Hruby lens has got a long handle which is fixed on the slot or groove, on the slit lamp meant for it. The joystick is moved forward so that the

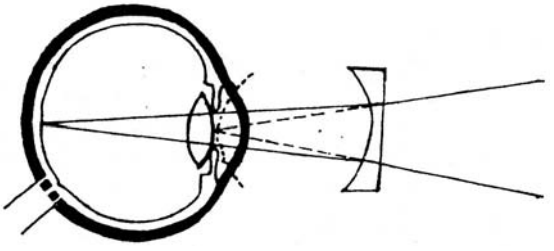


Fig. 9.21: Optics of Hruby lens. Location of virtual image depends on how close the lens is to patient's eye

lens comes in front of the eye to be examined. It is gradually brought closer till the retinal image comes. The joystick is adjusted so as to get the best view of the fundus. Slightly more than the posterior pole is visible if the patient is asked to look up, down, to the right and to the left. The lens is now focussed on the part to be examined. The angle of view of the fundus also increases if the lens is brought closer to the patient's eye.

78D AND 90D LENSES

These lenses are very useful for a quick survey of the retina particularly the central part. It's principle is same as that of the Hruby lens but unlike the latter it is not fixed and can be tilted side to side and up and down to get more view of the retina which is magnified and inverted. Because of these advantages it has practically replaced Hruby lens.

Method Disc and macula can be examined in undilated pupil but it is better to dilate because it becomes much easier to see and more of the retina is visible. The patient's chin is placed properly on the slit lamp. The lens is held in either hand which ever is comfortable for the examiner. The joystick of the slit lamp is held with the other hand. It is better to hold the lens in the thumb and index and middle finger. The lens is brought close to the patient's eye while the slit lamp is focussed on the lens. Gradually the lens is moved away and slit lamp is also moved till a point is reached where the fundal glow comes. Minor adjustment of the lens or the slit lamp gives a clear image of the fundus and slight tilting of the lens or the patient's eye helps to view the desired area of the fundus.

PANFUNDOSCOPE

It is a type of contact lens where the whole of retina can be seen due to a wide angled lens. It is seen with a slit lamp and is possible to photograph (Fig. 9.22). 78D and 90D are types of Hruby lens except that these cannot be mounted on the slit lamp. Therefore, these are held in front of the eye to be examined.

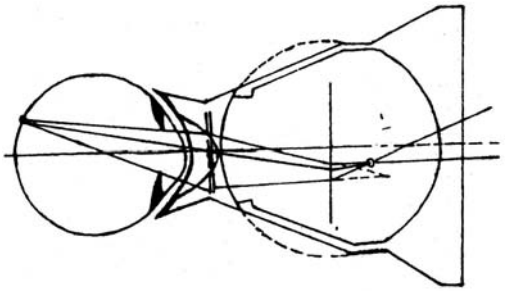


Fig. 9.22: Optics of panfundoscope

Rodenstock Panfundoscope

The unit contains a high plus contact lens which form an inverted fundus image located inside a second, spherical glass element without moving the lens the view reaches 200°, i.e. from equator to equator, 2 to 5 times the diameter of regular indirect ophthalmoscope. The main use of the lens is not for it's magnification but is for its overview.

SCANNING LASER OPHTHALMOSCOPE (SLO)

SLO is a unique instrument that can generate high quality detailed fundus images for objective analysis of the retinal structure and can also enable the examiner to project stimuli to very specific areas of the retina, thereby gathering highly sensitive information about retinal function. Fundus information is achieved by real-time electronic visualisation for data and image processing.

SLO uses a novel optical principle. Rather than to illuminate the retina and bring the reflected light to focus on film (as in conventional fundus photography) the SLO uses a very low power laser that is brought to extremely sharp focus (about 10 μm) onto the surface of the retina. Scanning devices consist of a beam of light, which sweeps over the object, delivering all its energy to a very small spot in a very short time. The laser beam is scanned across the retina at the same rate and in the same pattern that an electron beam moves across a television screen. The reflected light is not brought back to a sharp focus but, rather is presented to a very sensitive light detector, where the light energy is transduced and amplified. The energy returning is detected and synchronously decoded to form an image on an electronic display medium. A picture of retina is assembled by measuring the reflectance of the retina as the laser beam scans across it. A computer controls the position of the laser beam and is used to add appropriate synchronisation signals to the output of the amplifier so that a requlr video signal is produced, which can be shown on any television screen. Any laser can be installed in the SLO. Currently infra-red, red, green and blue wavelengths are used. The blue wave length is used for fluorescein angiography, the finfra-red wavelength for indocyanin green angiography and the green wave length for "red free" photographs prior to angiography. Red wavelength is used to provide a fixation target during indocyanine green angiography and to obtain preinjection photographs through nuclear sclerotic cataracts that excessively scatter the green light.

Rodenstock SLO is equipped with optics that provide 40° and 20° fields of view. As there are only 486 visible raster lines in NTSC (National Television Standards Committee) video, one might expect less resolution compared to the resolution achievable with conventional photography or with other digital photography techniques. But, with high magnification 20° field, these 486 raster lines are spaced 8-10 μm apart on the retina, which is nearly at the limits of diffraction for the optics of the human eye. Thus the resolution of the SLO on the retina often exceeds that of conventional photography.

Advantages of SLO

1. The images are obtained at a rate of 30/sec compared to 1/sec or slower in conventional photography. This allows a clinician to perceive events not visible in standard static photographs, e.g. numerous hyperfluorescent dots (nature still disputed) are seen moving in the perifoveal capillaries. The behaviour of the dots has been shown to change with disease.
2. It requires much less light than conventional photography (100 to 1000 times less). Since ICG fluoresces only 1/25 as efficiently as fluorescein, the amount of light required for ICG angiography with conventional photography could harm the retina. But SLO is an excellent instrument for ICG angiography.
3. Output of the red laser is modulated so that it can act as a harmless, high resolution target while simultaneously allowing the clinician to view that part of the retina.
4. Although SLO produces a video signal, the SLO is very different from a video camera attached to a fundus camera. The scanning feature of the SLO provides a very short exposure times for small objects. It provides much less subject blurring and can greatly increase contrast over regular photography.
5. Fluorescein angiography and ICG angiography obtained by SLO could be easily and conveniently interpreted. Since there is no processing of photographic film, the angiogram can be reviewed immediately. The instant feedback provided by the video enables the clinician to optimise laser power and video gain settings and to examine any area of special interest with high magnification.
6. Small pupil enables SLO to obtain visible images in cases in which the patient's pupil does not dilate.
7. SLO's high sensitivity to light allows for acceptable fluorescein angiogram when small amounts of fluorescein are administered (even with 0.5 ml of 10% fluorescein).
8. Digitized SLO images allows to produce simple overlays to confirm that laser treatment for subretinal neovascularisation completely

cover the neovascularisation. The pre-treatment and post-treatment fluorescein angiographic images are superimposed by selecting three corresponding points on the two images and making these points exactly the same. The locations of the other points are interpolated. The two images are then shown simultaneously with false colours so that pre-treatment image (in shades of red) is seen simultaneously with the post-treatment image (in shades of green). Digital thresholding will help in confirming the borders of the laser treatment.

Shortcomings of SLO
It provides no stereo information though the SLO can be moved side to side in the same way as a conventional fundus camera or a modified Allen separator can be used to fit onto the SLO to acquire right and left perspective images. With stereovideo goggles, high quality static stereo images are seen directly on the video screen.

ULTRASONOGRAPHY

Application of ultrasound waves to deflect underwater targets were first made in 1916. Gradually it was being used for industrial purposes. Ophthalmic ultrasound was first reported by Mendt and Hughs (1956). It gained importance over the years as, experience on the interpretation and research made diagnosis more accurate.

PARTS OF AN ULTRASOUND
1. Probes or Transducer.
2. Black box: (a) pulse emitter, (b) receiver, (c) amplifier, (d) signal processor.
3. Display.

Transducers
The most important and amazing part of the ultrasound unit is the transducer. It transforms electrical energy to sound energy which is directed to the tissues. The reflected sound waves are then received by the ceramic plates which converts the sound energy into electrical energy.

The electrical impulses are sent in short pulse and between two such pulses, it receives the dampened returning echoes. This cycle is repeated many thousand times per second. The frequency of the sound waves emitted is measured in cycles per second or Hertz (Hz). Ophthalmic ultrasound have frequency of 10 MHz. or 10 million cycles per second. The higher the frequency the less deeply its sound can penetrate. In body scanning low frequency is used (2.5 MHz to 5 MHz) for better penetration sacrificing resolution.

Black Box
Sound waves received by the receiver is sent to the amplifier, where it is enlarged or amplified. These amplifeid sound waves are now sent to the signal processor.

Here the signal is processed through highly sophisticated electronic devices and are then displayed on the display screen.

The display may be in two modes—A Scan and B Scan.

A scan (time amplitude) It is a one-dimensional display. The horizontal dimension is proportional to time and the vertical deflection denotes the position of echo (Fig. 9.23A).

B scan (intensity modulation or bright turn) It is two dimensional display. Here the horizontal dimension is still related to time and distance but the vertical echoes of A scan are represented as bright intensity modulated dots. By judging the various bright dots as well as the space it is possible to interpret any normal or abnormal structure of the eye (Fig. 9.23B).

PRINCIPLE
The sound waves entering the eye get back to the transducer after hitting the tissues it meets on the way. The height and brightness of these echoes depend on three factors.

Angle of incidence The sound waves behave exactly like light waves. If it is reflected from the surface at 90^{o} to the angle of incidence, the whole of sound enters the transducer, and will produce a bright image.

Acoustic impedence When the sound waves pass through different tissues, the sound

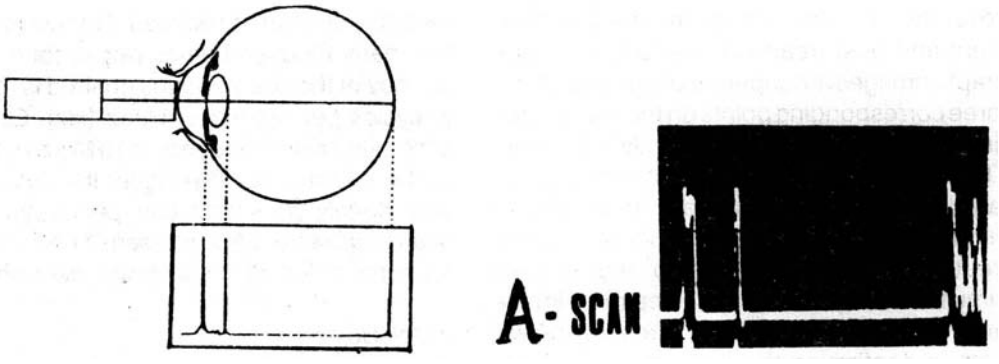


Fig. 9.23 A: In A scan, returning echoes are seen along time baseline as vertical deflection. Height of each vertical deflection is proportional to echo intensity

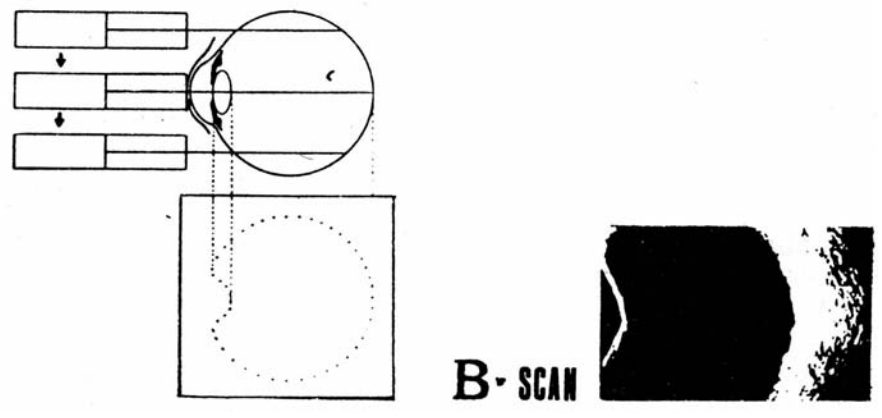


Fig. 9.23 B: In B scan, returning echoes are seen as intensity modulated dots. With gray-scale, strongest echoes appear white while weaker echoes are shades of gray, depending on their strength

propagation velocity and density between 2 adjacent tissues produces an echo.

Acoustic impedence means how easily the sound waves move. The more the difference between 2 tissues, the stronger or brighter is the image.

Texture and size of interfaces Smooth surface like a detached retina will produce a weaker echo, than a membrane with folds.

A Scan

Easy availability of B scan has limited the A scan only for axial length measurements of the eye. Its importance has increased and has become an integral part of biometry for intraocular lens implantation (Fig. 9.24, Plate 21).

Ocular echoes will be seen at the following structures:

Cornea Two peaks will be visible, i.e. one for the anterior surface and the second for the posterior surface with a very short gap giving a split hair appearance.

Lens One tall sharp echo from anterior lens and another tall sharp echo from the posterior lens surface. The difference between the two peaks is the lens thickness. The intervening area between these two peaks may be clean if the lens is clear

or even if there is cataract without any change in the lens material (Fig. 9.25, Plate 21).

In case of nuclear cataract two extra peaks between lens peaks may be seen due to the anterior and posterior surface of nucleus.

Vitreous This will produce no echo except if there is a pathology. Benign conditions such as floaters, asteriod hyaloides or serious conditions like vitreous haemorrhage will produce echoes.

Retina The most important echo for axial length measurements is the retinal echo. It should be a high sharply rising echo. Since measurement of axial length requires the beam to pass through the centre of the eye to the macula, anything other than a sharply rising echo could be due to the two following things:

i. Beam not perpendicular to the retina.
ii. Retinal pathology like pre-retinal membrane, haemorrhage, posterior staphyloma, etc.

The anterior corneal echo to the retinal echo is the axial eye length.

Sclera and orbital fat These will also produce echoes but it is outside the purview of the chapter.

Limitation of A Scan

Retinal tumours or retinal detachment or even vitreoretinal membranes may not be visible. This is because of the fact that A scan is a static scan (or the probe is kept straight and static) and there is every possibility that it will miss the area where the above abnormality lie.

Limitation of B Scan

This mode being two-dimensional, gives all the necessary information one would like to have.

Vitreous opacities, haemorrhages, retinal detachments, intraocular foreign body, intraocular tumours, or even extraocular tumours and condition of the globe after ocular injuries.

Since the probe is moved all around the globe no pathology is missed.

METHOD OF PERFORMING ECHOGRAMS

A Scan

1. Two per cent or four per cent lignocaine drop is instilled in the eye to be examined.
2. Put on the ultrasound unit and touch the transducer probe on the centre of the cornea asking the patient to look straight forward.
3. Axial length measured by the ultrasound comes out on the screen.
4. It is very important to see that it is pressed upon the cornea very lightly (Fig. 9.26, Plate 22).

B Scan

1. Put coupling gel on the eyelid.
2. Put the transducer probe on the closed lid after putting on the unit. The eye is examined in different positions by asking the patient to look up, down, right, left, up and right, etc. in all the positions of gaze.
3. This closed eye technique is useful in operated eyes, traumatised eye or children but has few shortcomings. It is not possible to know which way the patient is looking and secondly some amount of energy is lost, to penetrate the lids (Fig. 9.27, Plate 22).

EXAMINATION TECHNIQUES

The contact method, in which the probe is placed directly on the globe is used to evaluate the posterior segment. When anterior segment needs evaluation, an easy immersion technique has been developed that can be performed with the same instruments used for the contact examination.

The patient must be in reclining position. The echographer seats on an adjustable examining stool, usually to the patient's right. Fixation light, suspended from the ceiling, is useful to facilitate steady gaze. The patient's head and the instrument should be situated close, so that the probe position and the screen may be viewed simultaneously. Topical anaesthetic drops are applied to the eyes before the examination.

A Scan Examination Technique

A scan instrument is first adjusted to the tissue sensitivity gain setting. The patient's gaze is directed initially toward the 12 O'clock position, and the probe is placed flush on the globe at the 6 O'clock limbus. The probe is then slowly moved

into the fornix as the examiner tries to find out for the appearance of a lesion. This limbus to fornix manoeuvre is done in eight clock meridians, moving the probe temporally around the globe (Right eye → clockwise; Left eye → anticlockwise), until the posterior segment is thoroughly screened. During the examination, the patient's gaze is always directed towards the meridian being examined.

The basic A scan screening examination can also be performed at a reduced gain setting. The lower decibel level provides better resolution for the detection of relatively flat fundus elevations, overlooked at the higher tissue sensitivity setting.

Finally, two meridians (located 90° apart) are screened from limbus to fornix using tissue sensitivity plus 6 to 9 db in order to detect fine, diffuse vitreous opacities undetected at the tissue sensitivity setting.

B Scan Examination Technique

The two-dimensional B scan is the primary method for determining lesion topography (i.e. location and configuration). By obtaining echograms from a variety of probe positions, the echographer may then construct a mental three-dimensional configuration of the lesion.

All B scan probes contain a transducer which moves rapidly back and forth near the tip of the probe. The probe face is often oval shaped, with the back and forth motion of the transducer occuring in the longest diameter of the probe face. Each probe has a marker, usually a dot or a line, which indicates the side of the probe that is represented on the upper portion of the B scan screen. The probe face is always represented by the initial line on the left side of the echogram. The fundus, located on the side of the globe opposite to the probe position, is represented on the right side of the echogram. The upper part of the echogram corresponds to the position of the globe where the probe marker is directed. The centre of the screen corresponds to the central portion of the probe face.

Methyl cellulose is applied to the probe face as a coupling medium. The B scan probe is then placed directly on the globe (cornea or conjunctiva). Examination through the lids may cause sound attenuation produced by the lid tissues. In addition when the lids are closed, the echographer cannot be certain of which portion of the globe is being examined.

The three basic probe orientations used to evaluate intraocular lesions are—transverse, longitudinal, and axial. The transverse and longitudinal scans are used most commonly because the probe is placed on the conjunctiva peripheral to the cornea. Thus, the sound beam bypasses the lens, allowing better sound penetration. Scanning is done with the patient looking away from the probe to the meridian being examined, thus allowing a wide surface of globe on which probe can be placed and shifted. In the axial scan, the patient fixates in primary gaze and the probe is placed on the centre of the cornea, thereby displaying the lens and the optic nerve in the centre of the echogram.

Transverse scans The probe, here, is placed on the globe, with the largest diameter of the oval probe face oriented parallel to the limbus. Thus, the back and forth movement of the transducer occurs parallel to the limbus. The sound beam then oscillates back and forth across the opposite fundus, producing a circumferential slice. This method is best for showing the lateral extent of the lesion. The designation of the transverse scan is determined by the meridian that lies in the middle of the scanning section. By convention, horizontal transverse scans are performed with the marker oriented towards the patient's nose. The upper part of the echogram, thus, always represents the nasal portion of the globe. Vertical transverse scans are performed with the marker directed superiorly so that the top of the echogram represents the upper portion of the globe. Oblique transverse scans are performed with the marker directed towards the upper portion of the globe (Fig. 9.28A).

Longitudinal scans Here, the probe face is rotated 90° from the position used for the transverse scan, i.e. the longest diameter of the oval probe

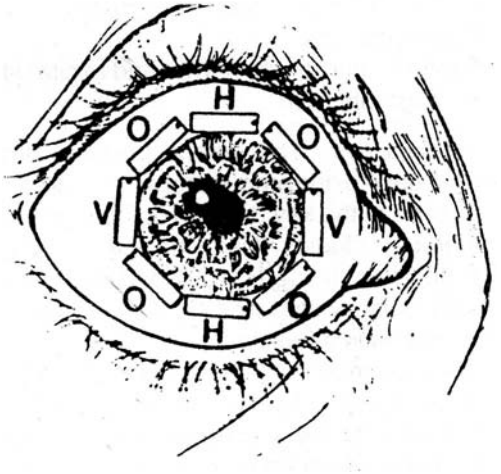


Fig. 9.28A: Probe marker orientations for various transverse B scan approaches: H—Horizontal probe postions, O—Oblique probe positions, V—Vertical probe positions

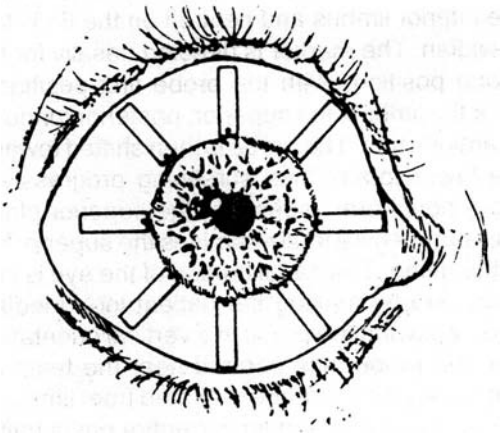


Fig. 9.28B: Probe marker orientation for various longitudinal B scan approaches. Probe marker is always oriented towards the centre of the cornea

face is placed perpendicular to the limbus. The sound beam then sweeps along the meridian opposite the probe rather than across the meridian, in contrast to the transverse scan. Thus, the longitudinal scan shows the anterior-posterior extent of a lesion. Here, the marker is always directed towards the centre of the cornea and of the meridian that is being examined. This produces an echogram where the optic disc and the posterior fundus is displayed on the lower portion of the screen, whereas the peripheral globe is displayed on the upper aspect of the screen. The designation of the longitudinal scan is simply that meridian which is being examined. With the probe placed for the longitudinal scan orientation, it is possible to shift the probe on the globe either closer to the limbus or into the fornix. This provides either a more posterior or a more anterior view of the meridian being examined. By placing the probe in such a way so that it slightly overlaps the limbus, the sound beam sweeps through more of the posterior aspect of the eye, thus allowing better evaluation of the peripapillary region. Conversely, when the probe is placed close to the fornix the sound beam extends more peripherally to better display the peripheral fundus and often the posterior ciliary body. The longitudinal approach should always be used to determine a membrane inserts into the optic disc and also for demonstrating the peripheral insertions of a membrane (Fig. 9.28B).

Axial scans It is performed with the patient fixating in primary gaze and with the probe face centred on the cornea. The sound beam is then directed through the centre of the lens sweeping along two opposing meridians, intersected by the optic nerve. Sound attenuation and refraction from the lens often hinder resolution of the posterior portion of the globe. This position is helpful for documenting lesions and membranes in relation to the lens and optic nerve and also for evaluation of the macular region. When a horizontal axial scan is performed, the marker is oriented towards the patient's nose, which places the macular region just below the optic disc in the echogram. A vertical axial scan is obtained (1:30 to 7:30 or 10:30 to 4:30 meridians), the marker is oriented towards the upper of the two meridians being scanned.

Transverse scans of the four major quadrants are performed initially at a high gain setting. The superior part of the globe is first scanned with the patient's gaze directed superiorly. The probe is

oriented horizontally with its face placed next to the inferior limbus and centred on the 6 O'clock meridian. The marker is directed nasally for this probe position. With the probe first positioned near the limbus, the superior, posterior fundus is examined first. The probe is then shifted towards the lower fornix; thus screening progressively more peripheral aspects of the superior globe. This manoeuvre thus examines the superior half of the globe. The nasal portion of the eye is next examined by making the patient look medially and by placing the probe in a vertical orientation, with the probe face centred near the temporal limbus. Again the probe is shifted from limbus to fornix, thereby scanning the entire nasal half of the globe. Similar manoeuvres are then performed for the inferior and temporal quadrants. The eye must be screened using longitudinal scans, along at least the four major meridians. The additional use of longitudinal scans can be useful for detecting lesions located in the peripapillary region as well as at the macula. These scans are also helpful for identifying lesions in the far periphery of the globe. The globe is then evaluated with both vertical and horizontal axial scans. For both of these portions, the patient fixates in primary gaze with the other eye and the probe is centred on the cornea of the examined eye. The B scan screening procedure is performed at both high and low gain settings. The high settings are used to detect vitreous opacities and gross fundus lesions, whereas the lower settings, which improve resolution, are helpful for detecting relatively flat fundus elevations and for better showing the topography of large lesions.

FLUORESCEIN ANGIOGRAPHY

Fluorescein angiography has been a major breakthrough in recent years. It is used for many retinal diseases to get a clear picture of the diagnosis as well as to anticipate the prognosis.

Diabetic and hypertensive retinopathy, venous occlusion, central serous retinopathy, macular degenerations, central choroidities disc oedema or pseudopapillites are some of the conditions where the role of fluorescein angiography is immense.

Essentials for Fluorescein Angiography

1. Fluorescein dye.
2. Fundus camera with barrier and exciter filter.
3. Photographic film.

Fluorescein dye The unique property of this agent, to absorb and emit light of different frequencies has been the key factor in doing fluorescein angiographic studies. It is being used as sodium salt of fluorescein ($C_{20}H_{10}O_5Na_2$) because of its low molecular weight and high water solubility facilitating rapid diffusion.

Fluorescein absorbs light between 480-510 nm. This absorbed light initiates molecular excitation elevating the electrons to a less stable form. These electrons then return to the stable form emitting rays between 510 to 530 nm.

The dye binds to plasma albumin mainly and accounts for 40-60 per cent of the total. It also binds to RBC (about 15%).

Toxicity It is relatively nontoxic. Nausea, vomiting, yellow discolouration of skin, urine (persisting for about 12-24 hours) and dyschromatopsia — yellowish hue of the visual field may occur. Extravasation of dye may cause severe pain with tissue necrosis.

Fundus camera Basic requisites of a fundus camera for fluorescein angiography are (Fig. 9.29, Plate 22).

1. 35 mm single lens reflector camera.
2. Strong excitor light with an excitor filter.
3. Barrier filter.
4. Electronic flash synchronisation for automatic flash with timer.
5. Blue filter for observation light.

The excitor light is a strong beam of light which has an excitor filter which absorbs all light except between 480-530 nm. The light is absorbed by the fluorescein in the circulation.

The barrier filter cuts off all rays except that emitted by fluorescein (510-530 nm) and allows it to fall on the film.

Photographic film Black and white film is preferred as there is no advantage using a colour film. For black and white 400 ASA film and for colour photographs 100 ASA is used (Fig. 9.30, Plate 22).

Method

a. It is very important to tell the patient about the whole procedure beforehand to get consent and gain confidence.
b. 3 cc of 20 per cent fluorescein sodium is used for the procedure. (10 ml of 5% or 5 ml of 10% can also be used). An emergency medical kit should always be kept ready.
c. Full dilatation of the pupil is required with tropicamide, homatropine and phenylephrine.
d. Fluid and food restriction for 3-4 hours before injection is important to prevent vomiting.
e. Place the chin of the patient on the chinrest after the camera is loaded and set.
f. Tie tourniquet around the arm and ask the assistant to get ready with the injection.
g. After inserting the blue filter a control photograph is taken.
h. Fluorescein is injected in bolus and series of photographs are taken after the choroidal flush appears.
i. After taking the late photographs the film is sent for processing.

Interpretation

Interpretation of the fluorescein angiographic plate is based on the following facts.

Choroidal flush It appears about 8-10 seconds after the injection (being the time for arm to retina circulation).

Arterial phase It comes immediately afterwards when the superior and inferior arterioles start filling.

Arteriovenous phase At this stage, the dye is seen both in the arterioles as well as the veins. Capillaries are also filled up but they are better seen, in the later stages.

Venous phase The initial period shows lamellar flow of dye and gradually the whole of the blood vessel is filled up.

Late phase or recirculation phase This stage means that the dye has been in recirculation, as a result the vessels start becoming less deep. The tissues which are normally unstained in health, starts leaking or pooling of dye occurs.

The fovea is avascular hence there is no fluorescence but parafoveal vascular arcade is seen.

Any abnormality or deviation in the fluorescence pattern has to be studied and correlated with the clinical findings.

ABNORMAL FLUORESCENCE

Interpretation of FFA is based upon two important features, i.e. the blood retinal barrier and the barrier between the choroid and RPE. Both RPE and xanthophyll pigment form a natural barrier to fluorescence. These natural barrier phenomenan provide informations as to the integrity of retinal vessels and RPE. Blocking of fluorescence creates hypofluorescence, whereas excessive fluorescence produce hyperfluorescence.

Hypofluorescence

Masking It is made by the following excessive pigments:

i. Melanin—in negroes and other heavily pigmented races, the choroidal masking is exaggerated due to presence of excessive pigments in RPE.

   If there is hyperplasia of RPE or choroidal nevus then same phenomenon will occur due to presence of excessive pigments.
ii. Blood and lipofuscin—also give a similar result.
   - Lipofuscin, e.g. malignant melanoma
   - Blood, e.g. choroidal haemorrhage, retinal haemorrhage, subhyaloid haemorrhage.
iii. Xanthophyll pigments (e.g. macular pigments) and dark fundus (e.g. some macular dystrophies) may cause masking.
iv. Serous fluids in between interphase, e.g. CSR, retinal detachment and disciform degeneration behave in the same way.
v. Both hard and soft exudates mask the choroidal background fluorescence during the early part of the angiogram.
vi. A so called dark fundus is seen in some cases of inborn error of metabolism, e.g. Tay-Sach's disease and some mucopolysaccharoidosis and lipidosis.

Filling defect Occlusions of the blood vessels of the choroid and retina—whether artery, vein or capillaries—show a partial filling defect of the appropriate layer.

Hyperfluorescence

Transmission defects (window defects) Deficiency in the RPE due to degeneration and atrophy allows visualisation of the choroidal circulation during the early phase of the angiogram. This is also called window defects.

In albinos due to lack of pigment hyperfluorescence is noted.

Abnormal vessels Abnormal blood vessels, whether in the choroid, subretinal space, or retina, fluoresce brightly by fluorescein during the circulation of dye.

a. New vessels and collaterals in diabetes, venous occlusions.
b. Neovascular membrane in subretinal space in disciform degeneration.
c. Retinal telangiectasia in Coat's disease.
d. Tumour vessels in malignant melanoma, choroidal haemangioma, angiomatosis retinae, metastatic tumours and other neoplasms.

Leakage and staining Extravasation of dye, when occurs, would either fill a space containing exudate or transudate, or alternatively impregnate into the tissue. The first phenomenon is known as pooling of dye or leakage and the second staining:

a. A typical pooling of dye is seen in cases of CSR, retinal pigment epithelial detachment, neurosensory separation in disciform degeneration of macula.
b. Staining is commonly seen to occur around the diseased blood vessels, soft exndate, drusen and scar tissue.

INDOCYANINE GREEN ANGIOGRAPHY

Indocyanine green (ICG) is a dye which has been in use for quite a long-time to measure cardiac and hepatic function. Its role in ophthalmology has been recognised since the seventies.

Sodium fluorescein as a dye has certain limitations in the diagnosis of choroidal neovascularisation (CNV). Blockage of the underlying pathology by overlying haemorrhage, pigments and serosanguinous fluid may prevent accurate localisation of the CNV. ICG on the other hand absorbs and fluoresces in the near infra-red range (absorption 795-810 nm; emission 835-850 nm), it will suffer less alteration of fluorescence by the overlying disturbance than sodium fluorescein which absorbs and emits in the visible range. ICG has another advantage that it is 98 per cent protein bound which prevents rapid leakage from the fenestrated choriocapillaries and allows enhanced imaging of the choroid and its associated pathology.

Advantages of ICG Angiography

1. ICG angiography has poor resolution due to low level of fluorescence. Digital imaging system can now produce high resolution angiograms.
2. Infra-red images when captured in photographic films induced chromatic aberration. Video camera, on the other hand, are very useful as they produce good resolution of infra-red images.
3. In more than 85 per cent of cases CNVM cannot be diagnosed by fluorescein angiography due to new vessel membrane or haemorrhage. ICG is very useful in these cases.
4. Peak absorption wavelength of ICG matches with peak emission wavelength of diode laser. Thus dye enhanced diode laser photocoagulation (DEDLP) allows ablation of selective CNVM using less energy and greater precision than conventional laser photocoagulation.

Angiographic Technique

One or two ml of ICG dye containing 25 mg/ml is injected into the antecubital vein after preparing the solution (by dissolving ICG powder in sterile aqueous solution). In cases where the media is hazy or there is pigmented retina or poorly dilated pupil 50 mg dose is required.

ICG videography is then performed using an appropriate digital imaging system. When CNV is suspected late exposures of up to 30-60 minutes post-injection is performed.At this stage retinal

vessels and optic disc appear diffusely hypofluorescent.

As previously stated infra-red rays penetrate haemorrhage, pigments, etc. better than the visible light; and moreover, ICG being protein bound is retained to a greater depree in the CNVM resulting in late local hyperfluorescence.

Indications of ICG Videography

1. Pigment epithelium without well-defined CNVM.
2. Occult CNV due to overlying haemorrhage, serosanguinous fluid or pigment.
3. Residual or recurrent CNV after laser treatment.
4. Poorly defined CNVM in fluorescein angiography.
5. Choroidal tumours.

Advantages of Fluorescein Angiography over ICG Angiography in CNVM

1. In well-defined CNVM fluorescein angiography is superior to ICG angiography.
2. Fine capillaries at the edges on CNVM can be better visualised with fluorescein angiography.
3. Difficulty in obtaining stereoimages with ICG limits diagnostic capabilities when CNVM is in doubt or the anatomic level of hyperfluorescence is unclear.

An ideal method would be to perform ICG angiography and fluorescein angiography together. ICG angiogram is performed first followed by early and late fluorescein angiography and finally late ICG changes are obtained.

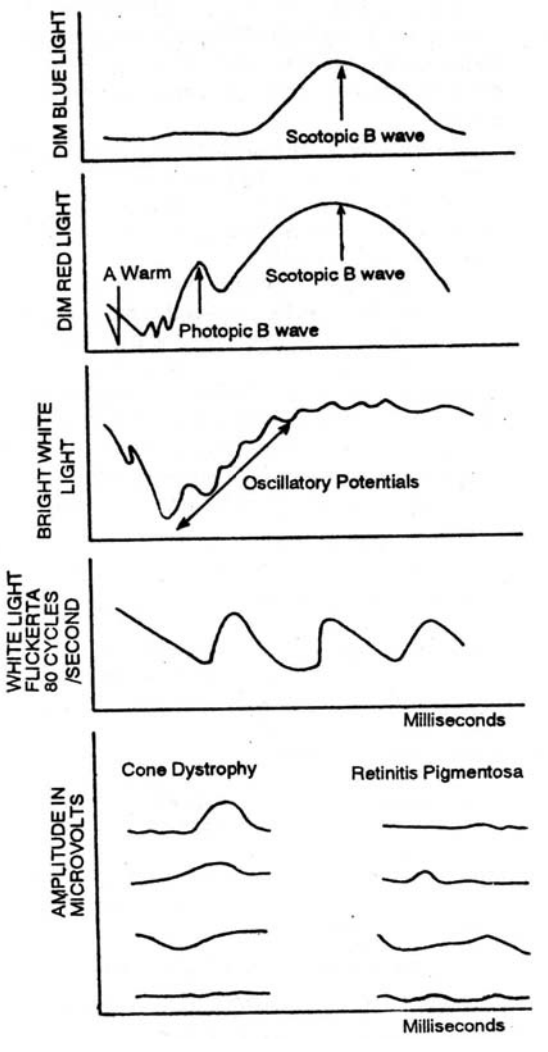


Fig. 9.31B: Measurement of ERG

ELECTRORETINOGRAM (ERG)

The ERG measures the mass retinal response to a flash of light using a corneal electrode and neutral electrodes placed on the skin around the orbital margin.

Neutral electrodes are first taped to the forehead and the orbital rim. The corneal electrode, which is a thin foil of gold leaf is placed gently behind the lower lid so that it contacts the cornea [Figs 9.31A (Plate 23) and 9.31B]. In infants ERG can be recorded umder general anaesthesia.

Due to different methods and techniques used to record ERG there is no typical response. There is usually a biphasic wave with an initial negative wave (a-wave) followed by a larger positive peak (b-wave). Oscillatory potentials are small wavelets noted on the ascending limb of the b-wave. The latency (from stimulus to the onset of a-wave), the

implicit time (from stimulus to peak of a-wave or b-wave) and the amplitudes of a-or b-waves can be measured. The ERG varies with the stimulus duration, intensity, colour and the state of retinal adaptation.

Origin of the a-wave is from the photoreceptor cells in the outer retina, that of b-wave is from the Muller's cells in the bipolar cell layer of inner retina and that of the oscillatory potential is possibly from the amacrine cells.

ERG can differentiate between rod and cone responses. This can be achieved either by measuring the responses under photopic or scotopic conditions, using red or blue light or the phenomenon of flicker fusion. The latter measures the ERG to a flashing light which increases in frequency until the photoreceptors can no longer differentiate the individual flashes, and the electrical signal is no longer recordable (Fig. 9.32).

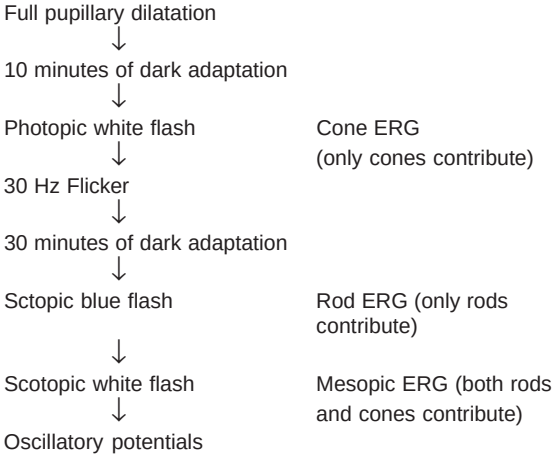


Fig. 9.32: Protocol for recording ERG

Further analysis of ERG shows that if a really intense stimulus is used, a deflection occurs preceding a-wave. This is called the early receptor potential (ERP) and probably correlates with the photochemical changes in the photoreceptors. Intense stimuli give rise to oscillatory potentials on the ascending amacrine cells in the inner nuclear layer.

Figure 9.31B shows the different wave forms obtained by altering the stimulus. Under dim blue light only the scotopic b-wave is recorded. With dim red light an a-wave is seen as well as photopic and scotopic peaks in the b-wave. An intense white light produces oscillatory potentials in the ascending limb of the b-wave. An intense white light produces oscillatory potentials in the ascending limb of the b-wave. In a normal patient discrete responses are seen in response to a flashing light of up to 80 cycles/second. The last Figure 9.31B shows the comparison between ERG responses in a patient with cone dystrophy and a patient with retinitis pigmentosa. In cone dystrophy the amplitude of the scotopic b-wave is normal, but the photopic b-wave is abolished (dim red). Response to bright light is present but reduced and delayed and discrete flicker responses are not elicited. In retinitis pigmentosa, the scotopic b-wave is absent, the photopic responses are present but reduced in amplitude, and flicker fusion is preserved.

ERG Interpretation

a. ERG in a generalized response will show an abnormality only if more than 30-40 per cent of retina is affected.
b. Delayed implicit times are typical of retinal degeneration and toxicities. It is also seen in presence of media opacities like cataracts.
c. Reduction or loss of b-wave amplitudes is seen in conditions affecting the inner layer of the retina, e.g. retinoschisis, diabetic retinopathy, CRVO, etc.
d. In rod-cone dystrophy (R.P.), the rod ERG is more affected than the cone ERG.
e. In cone-rod dystrophy, the cone ERG is more affected than the rod ERG.
f. Up to 15-20 per cent difference in amplitudes between the two eyes is considered normal.
g. A difference of more than 20-25 per cent at subsequent visitis is considered significant.
h. Media opacities, nondilating pupils, nystagmus can give rise to an abnormal ERG.
i. A clinical correlation is necessary before arriving at a diagnosis.

Indications for ERG

Cone-rod dystrophy, retinitis pigmentosa, congenital stationary night blindness, CRVO, retinoschisis, etc.

ELECTRO-OCULOGRAM (EOG)

Within the eye itself there is a standing potential between the retina and cornea of about 6 millivolts, with the cornea positive to the retina. This arises from the interactions in the retinal pigment epithelial layer. This potential can be measured by placing electrodes on the skin at the medial and lateral canthi and is basically a test for the retinal pigment epithelial layer.

The Technique

The pupils are dilated. Skin electrodes are attached near the medial and lateral canthi of both the eyes. A forehead electrode serves as a ground. The patient sits in front of two alternating fixation lights which cause the movement of the eyes from side to side with an excursion of about 30° of the horizontal movements [Fig. 9.33A (Plate 23) and Fig. 9.33B]. Movements of the potential between the electrodes induces a current which is then amplified and displayed on recording equipment. The potential which can be measured vaires according to the level of background illumination. After light adaptation for about 5 minutes, the lights are switched off the recordings are taken for 15 min (light insensitive part). The recorded potentials decrease progressively reaching a dark trough (Dt) in about 8 to 12 minutes. This light insensitive part depends on the integrity of the RPE layer. Lights are switched on and similar recordings are in light adapted conditions (light sensitive part). During light adaptation there is progressive increase in the potentials reaching a light peak (Lp) in 6 to 9 minutes. This light sensitive part depends on the integrity of RPE, photoreceptors and inner retina. The ratio (Arden's ratio) of the potentials measured in the light and dark is converted to an algebric fraction (Lp/Dt x 100) and this should be in excess of 180 per cent. Measurement lower than this represents retinal disease at the level of RPE.

Measurement of the EOG requires active co-operation of the patient. Although readings are not affected by opacities in the ocular media, low

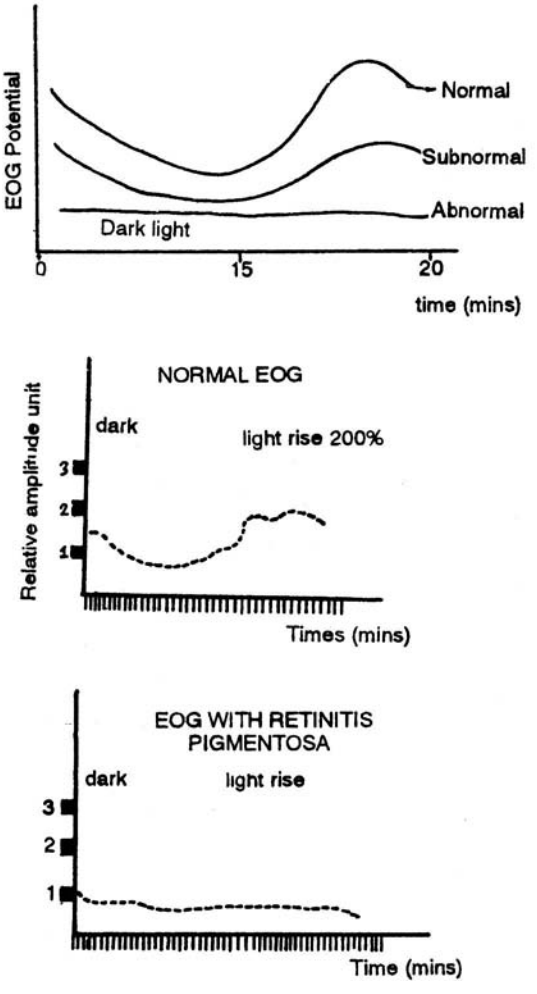


Fig. 9.33B: Measurement of EOG

responses can be seen normally in myopes, and in the elderly, and also after ocular surgery or injury. More than 10 per cent difference between the two eyes is significant. A difference of 0.6 in ratio with repeat EOG is significant.

Indications

Best's disease; Butterfly dystrophy; Chloroquine toxicity; Dominant drusen; Stargardt's disease, etc.

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